



(51) International Patent Classification:

A61B 5/145 (2006.01) A61B 5/00 (2006.01)

(21) International Application Number:

PCT/US2024/047778

(22) International Filing Date:

20 September 2024 (20.09.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/539,927 22 September 2023 (22.09.2023) US
63/696,713 19 September 2024 (19.09.2024) US

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,

(54) Title: DECISION SUPPORT FOR GLUCOSE-KETONE SENSOR

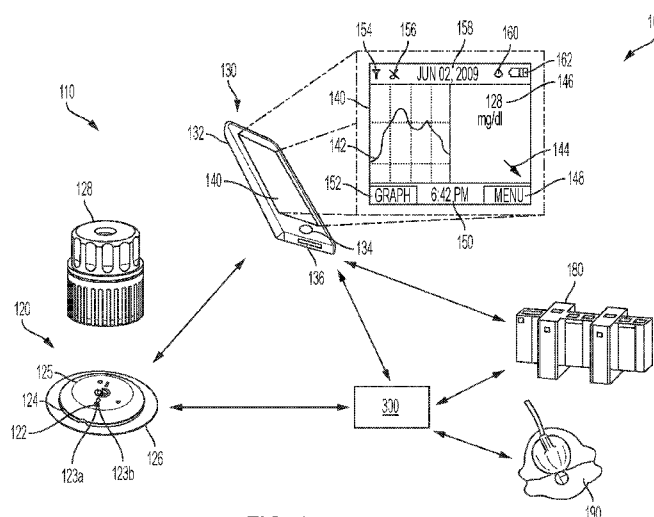


FIG. 1

(57) Abstract: A system includes an analyte measurement system and a software application operatively coupled to the analyte measurement system. The analyte measurement system is configured to measure a ketone level in the bodily fluid of a patient. The application is configured to display at least one of (1) a current ketone level and an indicator of a current ketone trend, (2) a ketone trend graph, and (3) a total amount of time that the ketone levels are above at least one predetermined threshold level. The application is also configured to determine if the current ketone level is above the at least one predetermined threshold level, and in response to determining that the current ketone level is above the at least one predetermined threshold level, output an alarm, wherein the alarm is outputted periodically while the current ketone level is above the at least one predetermined threshold level.

HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

DECISION SUPPORT FOR GLUCOSE-KETONE SENSOR

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 63/696,713, filed September 19, 2024, and U.S. Provisional Application No. 63/539,927, filed September 22, 2023, both of which are hereby expressly incorporated by reference in their entireties for all purposes.

FIELD

[0002] The present disclosure relates to analyte monitoring apparatuses, systems, and methods, for example, software application apparatuses, systems, and methods for detecting, notifying, and preventing adverse analyte conditions.

BACKGROUND

[0003] The detection and/or monitoring of analyte levels can be vitally important to the health of an individual having diabetes. Patients suffering from diabetes mellitus can experience complications including loss of consciousness, cardiovascular disease, retinopathy, neuropathy, and/or nephropathy. Diabetic ketoacidosis (DKA) is a potentially life-threatening complication of diabetes mellitus. DKA results from a shortage of insulin, which in response the body produces acidic ketone bodies. Generally, DKA happens with type-1 diabetes patients, but it can occur under certain circumstances with other diabetes types.

[0004] People with diabetes (PwD) are generally required to monitor their glucose levels to ensure they are maintained within a clinically safe range, and may also use this information to determine if and/or when insulin is needed to reduce glucose levels in their bodies or when additional glucose is needed to raise glucose levels in their bodies. A number of systems allow individuals to monitor their blood glucose, for example, continuous glucose monitoring (CGM). Some of these systems include electrochemical biosensors, including those that use a glucose sensor adapted to be positioned in vivo, for example, with complete or partial insertion into a subcutaneous or transcutaneous site, within the body for continuous in vivo monitoring of glucose levels from bodily fluids of the site.

[0005] Growing clinical data demonstrates a strong correlation between the frequency of glucose monitoring and glycemic control. Despite such correlation, many PwD do not monitor their glucose levels as frequently as they should due to a combination of factors including

inconvenience, testing discretion, pain associated with glucose testing, and/or cost. For patients that rely on the administration of medications (e.g., insulin, SGLT-2 inhibitors) to treat or manage diabetes, it is desirable to have systems, devices, and/or methods that can integrate glucose data with insulin dosing data and provide more actionable insights to patients, caregivers, health care professionals (HCPs), and/or primary care physicians (PCPs).

[0006] SGLT-2 inhibitors, also called flozins, are a class of medications that modulate sodium-glucose transport (SGLT) proteins in the nephrons of the kidney, thereby inhibiting reabsorption of glucose and lowering blood sugar. SGLT-2 inhibitors can increase the risk of DKA, and specifically can cause euglycemic DKA (euDKA), where the blood sugar is not elevated due to absorption of ketone bodies. EuDKA causes high ketone levels with normal glucose levels. Patients (e.g., type-1 diabetes patients) that use certain medications (e.g., SGLT-2 inhibitors) are at risk of euDKA.

[0007] Continuous monitoring of additional analytes can be utilized to detect an adverse condition in real-time, for example, an adverse glucose-ketone condition (e.g., euDKA). However, although discrete ketone test strips, along with CGM, are available, these systems are impractical and/or insufficient for continuous monitoring of ketones. Further, it is complex and difficult for a patient to correctly interpret additional analyte levels and determine the appropriate action, requiring the patient to contact a HCP for proper interpretation and guidance.

SUMMARY

[0008] Accordingly, in some aspects, a system can include a software application that can detect current or impending adverse conditions (e.g., glucose-ketone conditions), provide custom notifications (e.g., warnings, recommendations, guidance) to the patient to act, prompt the patient for additional information relevant to the detected condition, continuously monitor glucose and ketone levels in real-time, control insulin delivery based on ketone level, and mitigate the risk of euDKA. Further, there is a need to deliver guidance to a patient at appropriate times and capture additional information (e.g., contextual data) about the patient's condition at the moment when the patient will remember it.

[0009] In some aspects, a system can include an analyte measurement system and a software application operatively coupled to the analyte measurement system. In some aspects, the analyte measurement system can be configured to measure a first analyte and a second analyte of a patient.

In some aspects, the analyte measurement system can include an analyte sensor and a display device. In some aspects, the software application can be configured to retrieve sensor data of first and second analyte levels, or multiple analyte levels. In some aspects, the software application can be configured to detect at least one condition associated with the sensor data. In some aspects, the software application can be configured to provide a notification to the patient associated with the at least one detected condition. Advantageously the system can detect current or impending adverse conditions (e.g., glucose-ketone conditions) and provide custom notifications (e.g., warnings, recommendations, guidance) to the patient to act at appropriate times. The conditions detected may be, for example, low, moderate or high glucose levels and/or low, moderate or high ketone levels.

[0010] In some aspects, the software application can be configured to operate on conditional logic associated with predetermined settings. In some aspects, the software application can be configured to adjust the predetermined settings. In some aspects, the predetermined settings can include a plurality of thresholds. In some aspects, the predetermined settings can include a first threshold value of the first analyte and a second threshold value of the second analyte, or threshold values for each of multiple analytes. In some aspects, the predetermined settings can include first and second threshold values of the first analyte and third and fourth threshold values of the second analyte, or multiple thresholds for each of multiple analytes. Advantageously the software application can utilize default or editable thresholds (e.g., glucose and ketone thresholds) to provide notifications (e.g., warning, recommendation, guidance, prompts) associated with each conditional logic state defined by the thresholds. These thresholds may also be automatically configured based on a set of predefined rules depending on, for example, past glucose and ketone data, past patient responses to prompts, known therapy information (e.g., elevated baseline ketone levels), known diet (e.g., ketogenic diet), other data that may be available to the system, or a combination thereof. These rules may be predetermined by humans or using machine-learning methods, or from a combination of both. Furthermore, these thresholds may be automatically configured based on rules that are adapted specifically for the patient based on past data collected by the system for the patient. This adaptive functionality would benefit the patient by tailoring the thresholds so they are more appropriate for the patients needs. For instance, some patients may benefit from a lower threshold of high ketone detection and earlier intervention of the high ketone condition, where as it may be more appropriate for other patients to have a higher threshold as they

can tolerate higher ketone levels and may be interrupted or annoyed by the high ketone alarm that is not appropriate for them. In this case, the threshold may be adapted based on, for example, prior glucose and ketone data, insulin delivery data, and user entered information regarding symptoms.

[0011] In some aspects, the software application can be configured to adjust the conditional logic based on a rate of change of the first analyte level and/or the second analyte level. In some aspects, the software application can be configured to adjust the conditional logic based on a rate of change of multiple analyte levels. In some aspects, the software application can be configured to adjust the conditional logic based on a rate of change of higher order derivatives (e.g., second-order derivative, third-order derivative, etc.) of the first analyte level and/or the second analyte level (e.g., glucose acceleration, ketone acceleration, etc.) In some aspects, the software application can be configured to adjust the conditional logic based on a rate of change of higher order derivatives (e.g., second-order derivative, third-order derivative, etc.) of multiple analyte levels (e.g., glucose acceleration, ketone acceleration, lactic acid acceleration, etc.) In some aspects, the software application can be configured to adjust the conditional logic based on insulin sensitivity, carbohydrate ratio, patient disease state, patient medication regimen, and/or pairing with a remote dose system. Advantageously the software application can adjust (e.g., optimize) the conditional logic based on one or more ranges of various parameters (e.g., glucose rate of change, ketone rate of change, insulin sensitivity, carbohydrate ratio, patient disease state, patient medication regimen, remote dose system, etc.) and/or one or more equations associating the various parameters with insulin dose amounts to define the predetermined settings (e.g., thresholds).

[0012] In some aspects, the first and second analytes can be measured continuously in real-time. In some aspects, the first analyte can be measured at a different frequency than the second analyte. Advantageously the system can continuously monitor glucose and ketone levels in real-time or retrieve and process sensor data in near real-time (e.g., every minute, every 5 minutes, every 10 minutes, etc.), thereby detecting current or impending adverse conditions (e.g., glucose-ketone conditions) at all times or at appropriate times of the day (e.g., low periodicity during morning hours). Further advantageously continuous ketone monitoring can account for dynamic effects of ketones, for example, on glycemic response.

[0013] In some aspects, the analyte sensor can include a dual analyte sensor to measure the first and second analytes. In some aspects, the dual analyte sensor can include two analyte sensor (e.g., two sensor tails) or two sections or sides on a same analyte sensor in the same on body unit (OBU)

to measure the first and second analytes. In some aspects, the dual analyte sensor can include individual microneedles to measure the first and second analytes. In some aspects, the analyte sensor can include two separate analyte sensors (e.g., separate OBUs) to measure the first and second analytes. In some aspects, the analyte sensor can include a multiple analyte sensor to measure multiple analytes (e.g., glucose, ketone, lactic acid, etc.). In some aspects, the multiple analyte sensor can include multiple analyte sensor (e.g., two sensor tails) or two sections or sides on a same analyte sensor in the same OBU to measure the multiple analytes. In some aspects, the multiple analyte sensor can include individual microneedles to measure the multiple analytes. In some aspects, the first analyte can be glucose and the second analyte can be ketone. Advantageously the system can measure and retrieve glucose and ketone levels, either from a single (dual) sensor for both analytes or from two separate sensors for each analyte, for continuous analyte (glucose-ketone) monitoring (e.g., real-time) or discrete analyte (glucose-ketone) monitoring (e.g., near real-time).

[0014] In some aspects, the system can further include an insulin delivery system operatively coupled to the software application. In some aspects, the software application can be configured to control the insulin delivery system based on the at least one detected condition. In some aspects, the software application can be configured to cause continuation of insulin delivery if the ketone level is above a high ketone threshold. In some aspects, ketone data can be used to inform and/or adjust a pump occlusion detection algorithm (e.g., pump-occlusion detection subsystem). For example, detection of elevated ketone levels can indicate a higher likelihood of an infusion set problem (e.g., pump occlusion). In some aspects, ketone data (e.g., elevated ketone level) can adjust a sensitivity and/or a specificity of the pump occlusion detection algorithm. Advantageously the software application can control insulin delivery from the insulin delivery system based on ketone levels, for example, mitigating euDKA by continuing insulin delivery if the ketone level is high (e.g., above 3.0 mmol/L), whereas normally an insulin delivery system may stop or decrease insulin delivery if only considering glucose levels (e.g., normal glucose level, glucose error detected, glucose fault detected).

[0015] In some aspects, the notification can include a warning to the patient associated with the at least one detected condition. In some aspects, the notification can include a warning or alert to another entity (e.g., caregiver, HCP, emergency services, third party, designated person, person nearby patient, etc.) associated with the at least one detected condition, for example, in addition to

the warning to the patient. For example, the warning or alert can be sent to another entity via a wireless or network connection (e.g., WiFi, cellular, 5G, thread, Bluetooth, etc.). In some aspects, the notification can include a recommendation for the patient to act associated with the at least one detected condition. In some aspects, the notification can include a recommendation to another entity (e.g., caregiver, HCP, emergency services, third party, designated person, person nearby patient, etc.) associated with the at least one detected condition, for example, in addition to the recommendation to the patient. For example, a recommendation or message can be displayed on a display device (e.g., phone, computer, etc.) for another entity to interpret (e.g., “Help, I have diabetes and have elevated ketone levels, please call emergency services”), for example, on the patient’s display device and/or on another entity’s display device. In some aspects, the software application can be configured to provide a second notification to the patient if the at least one detected condition remains unchanged after a predetermined time period. Advantageously the software application can detect current or impending adverse conditions (e.g., glucose-ketone conditions) and provide custom notifications (e.g., warnings, recommendations, guidance) to the patient and/or another entity (e.g., caregiver, HCP, emergency services, third party, designated person, person nearby patient, etc.) to act at appropriate times.

[0016] In some aspects, the software application can be configured to provide a prompt to the patient to retrieve additional information regarding the at least one detected condition. In some aspects, the additional information can include contextual data of the at least one detected condition. In some aspects, the software application can be configured to adjust a threshold value of the first analyte and/or the second analyte based on the contextual data. In some aspects, the contextual data can include a frequency of the at least one detected condition. In some aspects, the frequency can include a number of times the at least one detected condition occurs in at least one of 1 hour, 6 hours, 12 hours, a day, a week, a month, or a combination thereof. In some aspects, the contextual data can include a discomfort level of the patient. In some aspects, the contextual data can include contributing factors of the patient, medications taken by the patient, whether the patient received emergency medical services, or a combination thereof. Advantageously the software application can prompt the patient for additional information relevant to the detected condition at appropriate times. Further advantageously the software application can capture additional information (e.g., contextual data) about the patient’s condition at the moment when the

patient will remember it, for example, to assist a clinician or HCP determine an underlying cause of the condition.

[0017] In some aspects, the software application can be configured to perform analytics of the sensor data to determine a baseline first analyte level and/or a baseline second analyte level. In some aspects, the software application can be configured to perform analytics of the sensor data to determine a predictive model. In some aspects, the predictive model can be based on a population model and one or more parameters that modulate the predictive model into a range of known variations from the population model. In some aspects, the predictive model can be based on regression, model-based parameter adaptation, supervised machine learning, unsupervised machine learning, semi-supervised machine learning, reinforced learning, clustering, decision trees, anomaly detection, neural networks, classification models, or a combination thereof. Advantageously the predictive model can increase accuracy and precision of estimates regarding a patient's future glucose and/or ketone levels. Further advantageously the predictive model can estimate a likelihood of a high ketone condition and present the likelihood to the patient (e.g., a notification).

[0018] In some aspects, the system can further include a dose guidance system operatively coupled to the software application. In some aspects, the software application can be configured to provide a dose recommendation based on a glycemic response model. In some aspects, the glycemic response model can be based on basal insulin, insulin sensitivity, carbohydrate ratio, and the second analyte. In some aspects, the second analyte can include ketone or lactic acid. In some aspects, the basal insulin, the insulin sensitivity, and/or the carbohydrate ratio can be a function of the second analyte. Advantageously the glycemic response model can improve traditional insulin calculator (e.g., bolus calculator) by utilizing one or more additional analyte measurements (e.g., ketone, lactic acid) and/or additional information (e.g., basal insulin, insulin sensitivity, carbohydrate ratio). Further advantageously the glycemic response model can be modified to replace constant factors (e.g., basal insulin, insulin sensitivity, carbohydrate ratio) of the dose calculation by one or more functions of the second analyte level (e.g., ketone level, time series of ketone levels, ketone rate of change, etc.). Further advantageously continuous ketone monitoring can account for dynamic effects of ketones, for example, on glycemic response, thereby increasing accuracy of the glycemic response model.

[0019] In some aspects, the software application can be configured to retrieve additional data from a second sensor. In some aspects, the software application can be configured to retrieve additional data from multiple sensors, for example, in addition to the analyte sensor. In some aspects, the additional data can include activity data, heart rate, breathing rate, body temperature, perspiration data, position data, and/or lactic acid level. In some aspects, the additional data can include historical data of insulin infusion set changes (e.g., number of days from last infusion set change), historical data of insulin delivery (e.g., suspension(s) of the insulin infusion pump), and/or historical data of meals (e.g., ketogenic diet). Advantageously additional data (e.g., activity data, heart rate, breathing rate, body temperature, perspiration data, position data, lactic acid level, historical data of infusion set changes, historical data of infusion delivery, historical data of meals, etc.) from a second sensor or from multiple sensors can increase accuracy and precision of estimates of high ketone conditions. Note that these additional data may also be acquired from sources other than sensors, for instance, by manual entry means or imported from a connected health, fitness, or exercise application. Further advantageously a predictive model (e.g., a probabilistic model) can be made between the additional data and occurrences of high ketone levels to estimate a likelihood of a high ketone condition and present the likelihood to the patient (e.g., a notification).

[0020] In some aspects, the software application can be configured to titrate a dose based on the first analyte level and/or the second analyte level. Advantageously a medication dose amount (e.g., SGLT-2 inhibitor) can be automatically titrated (e.g., determine amount of constituent in a solution) by the system for the patient. Further advantageously titration can be based on ketone levels, other analyte levels (e.g., glucose), and/or other measurements (e.g., delivered insulin, carb intake, etc.) to determine if a medication (e.g., SGLT-2 inhibitors) dose amount should be increased, decreased, or maintained.

[0021] In some aspects, the software application can be configured to determine an erroneous reading based on the first analyte level and/or the second analyte level. Advantageously the second analyte level (e.g., ketone, lactate, lactic acid, alcohol) can be used to detect errors in the first analyte level (e.g., glucose, lactate, lactic acid, alcohol), and the first analyte level (e.g., glucose) can be used to detect errors in the second analyte level (e.g., ketone, lactate, lactic acid, alcohol). Further advantageously the software application can detect an indication of euDKA or an erroneous glucose reading (e.g., low glucose when glucose levels are actually high), based on high

ketone levels and low or normal glucose levels, and notify the patient accordingly to take appropriate action, for example, taking a blood glucose measurement (e.g., blood glucose test strip) to confirm the glucose level.

[0022] In some aspects, the software application can be part of the analyte measurement system. In some aspects, the software application can include a mobile application on the display device. In some aspects, the system can further include a remote server configured to support the software application. Advantageously the software application can all be contained in a patient mobile application (app) or some or part of the software application can be contained in a remote server (e.g., web-server, cloud server) that supports the software application, for example, with processing, communication, and/or reporting functionalities. Further advantageously the software application can include an application programming interface (API) for two or more computer programs to communicate with each other (e.g., conditional logic system, settings system, notification system, dose control system, etc.).

[0023] In some aspects, the software application can be configured to change a default home screen of the display device based on the at least one detected condition. Advantageously the default home screen can include glucose data (e.g., glucose level, glucose rate of change, glucose trend, etc.), but when ketone levels are elevated the default home screen can change to display ketone data (e.g., ketone level, ketone rate of change, ketone trend, etc.) or change so that both glucose and ketone data are displayed.

[0024] In some aspects, the software application can be configured to display a GUI including ketone data (e.g., ketone level, ketone rate of change, ketone trend). A current ketone level (e.g., most recently measured ketone level) can be displayed, along with a trend arrow to indicate a current trend of ketone levels. The software application can also display in the GUI a ketone trend graph of the current and/or stored ketone readings. The graph can include lines delineating at least one of 1.0 mmol/L, 1.5 mmol/L, 2.0 mmol/L, 2.5 mmol/L, and 3.0 mmol/L. The GUI may also include a ketone metric, such as time above a certain threshold. The threshold may be 0.5 mmol/L, 0.6 mmol/L, 1.0 mmol/L, 1.5 mmol/L, 2.0 mmol/L, or 3.0 mmol/L. In some embodiments, the current ketone level can be updated at a different rate than the ketone graph. The current ketone level can be updated at a faster rate than the ketone trend graph. For example, the current ketone level can be updated every minute while the graph can be updated every 5 minutes, alternatively

every 10 minutes, alternatively every 15 minutes, alternatively every 20 minutes, or alternatively every 30 minutes.

[0025] In some aspects, a method can include measuring a ketone level of a patient, and detecting at least one condition associated with the measured ketone data. The at least one condition may be when a ketone level is above a first threshold. The at least one condition may also be when the ketone level is above a second threshold. The at least one condition may also be when the ketone level is above a third threshold. For example, any one of the first, second, or third thresholds may be 0.5 mmol/L, 1.0 mmol/L, 1.5 mmol/L, 2.0 mmol/L, 2.5 mmol/L, or 3.0 mmol/L. The method may further include outputting a notification regarding the at least one condition. Outputting the notification may include outputting a sound, haptic notification, and/or visual notification. The visual notification may be a banner, a toast notification, or a window, or any other notification as is known in the art.

[0026] In some aspects, a method can include measuring a first analyte and a second analyte of a patient with an analyte measurement system, the analyte measurement system including an analyte sensor and a display device. In some aspects, the method can include measuring a plurality of analytes, for example, but not limited to, glucose, ketones, and lactic acid. In some aspects, an additional analyte (e.g., lactic acid) can be used as another measurement input to the analyte measurement system. In some aspects, the method can include measuring a first plurality of analytes, for example, but not limited to, glucose and ketones, and measuring a second plurality of analytes, for example, but not limited to, lactic acid and lactate. In some aspects, the method can further include retrieving sensor data of first and second analyte levels with a software application operatively coupled to the analyte measurement system. In some aspects, the method can further include detecting at least one condition associated with the sensor data. In some aspects, the method can further include providing a notification to the patient associated with the at least one detected condition. Advantageously the method can detect current or impending adverse conditions (e.g., glucose-ketone conditions) and provide custom notifications (e.g., warnings, recommendations, guidance) to the patient to act at appropriate times.

[0027] In some aspects, the method can further include providing a prompt to the patient to retrieve additional information regarding the at least one detected condition. Advantageously the method can prompt the patient for additional information relevant to the detected condition at appropriate times. Further advantageously the method can capture additional information (e.g.,

contextual data) about the patient's condition at the moment when the patient will remember it, for example, to assist a clinician or HCP determine an underlying cause of the condition.

[0028] In some aspects, detecting can include utilizing conditional logic associated with predetermined settings. In some aspects, the predetermined settings can include first and second threshold values of the first analyte and third and fourth threshold values of the second analyte. Advantageously the method can utilize default or editable thresholds (e.g., glucose and ketone thresholds) to provide notifications (e.g., warning, recommendation, guidance, prompts) associated with each conditional logic state defined by the thresholds.

[0029] In some aspects, measuring can include continuously measuring the first and second analytes in real-time. Advantageously the method can continuously monitor glucose and ketone levels in real-time or retrieve and process sensor data in near real-time (e.g., every minute, every 5 minutes, every 10 minutes, etc.), thereby detecting current or impending adverse conditions (e.g., glucose-ketone conditions) at all times or at appropriate times of the day (e.g., low periodicity during morning hours). Further advantageously continuous ketone monitoring can account for dynamic effects of ketones, for example, on glycemic response.

[0030] In some aspects, a system can include an analyte measurement system and a processor in communication with the analyte measurement system. In some aspects, the analyte measurement system can be configured to measure a first analyte and a second analyte of a patient. In some aspects, the analyte measurement system can include an analyte sensor and a display device. In some aspects, the processor can be coupled to a memory storing instructions that when executed cause the processor to: retrieve sensor data of first and second analyte levels, detect at least one condition associated with the sensor data, provide a notification to the patient associated with the at least one detected condition, prompt the patient to enter contextual data, save a record of the at least one detected condition along with the contextual data, and generate a report including the at least one detected condition and associated contextual data. In some aspects, the contextual data is associated with the at least one detected condition.

[0031] In some aspects, a system can include an analyte measurement system, a processor in communication with the analyte measurement system, and an insulin delivery system in communication with the processor. In some aspects, the analyte measurement system can be configured to measure a first analyte and a second analyte of a patient. In some aspects, the analyte measurement system can include an analyte sensor. In some aspects, the processor can be coupled

to a memory storing instructions that when executed cause the processor to: retrieve sensor data of first and second analyte levels, and detect at least one condition associated with the sensor data. In some aspects, the processor can be configured to cause the insulin delivery system to deliver insulin based on the first and second analyte levels.

[0032] In some aspects, the first analyte can include glucose and the second analyte can include ketone. In some aspects, an insulin dose can be calculated based on the glucose level. In some aspects, the calculated insulin dose can be further adjusted based on the ketone level. In some aspects, an insulin sensitivity can be adjusted based on the glucose and ketone levels. In some aspects, a carbohydrate ratio can be adjusted based on the glucose and ketone levels.

[0033] In some aspects, the system can further include a display configured to display one or more first trend arrows of the first analyte (e.g., glucose) and one or more second trend arrows of the second analyte (e.g., ketone, lactate, lactic acid, alcohol). In some aspects, the one or more first trend arrows and the one or more second trend arrows have the same number of trend arrows (e.g., one first trend arrow and one second trend arrow, two first trend arrows and two second trend arrows, etc.). In some aspects, the one or more first trend arrows and the one or more second trend arrows have a different number of trend arrows (e.g., one first trend arrow and two second trend arrows, two first trend arrows and one second trend arrow, etc.). In some aspects, the one or more first trend arrows and the one or more second trend arrows display the same rate of change unit of the first and second analytes (e.g., mmol/L/min, mg/dL/min, mmol/L/hr, mg/dL/hr, etc.). In some aspects, the rate of change unit is mmol/L/min. In some aspects, the one or more first trend arrows and the one or more second trend arrows display different rate of change units of the first and second analytes (e.g., mmol/L/min for the one or more first trend arrows and mmol/L/hr for the one or more second trend arrows, etc.). In some aspects, the one or more first trend arrows includes a flat arrow to indicate a different rate of change unit for the one or more first trend arrows than for the one or more second trend arrows. In some aspects, the one or more second trend arrows includes a flat arrow to indicate a different rate of change unit for the one or more second trend arrows than for the one or more first trend arrows.

[0034] Implementations of any of the techniques described above can include a system, a method, a process, a device, and/or an apparatus. The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

[0035] Further features and exemplary aspects of the aspects, as well as the structure and operation of various aspects, are described in detail below with reference to the accompanying drawings. It is noted that the aspects are not limited to the specific aspects described herein. Such aspects are presented herein for illustrative purposes only. Additional aspects will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

BRIEF DESCRIPTION OF THE FIGURES

[0036] The accompanying drawings, which are incorporated herein and form part of the specification, illustrate the aspects and, together with the description, further serve to explain the principles of the aspects and to enable a person skilled in the relevant art(s) to make and use the aspects.

[0037] FIG. 1 is a schematic illustration of an analyte monitoring system with a software application, according to an exemplary aspect.

[0038] FIG. 2A illustrates an analyte monitoring system flow diagram for the analyte monitoring system shown in FIG. 1, according to an exemplary aspect.

[0039] FIG. 2B illustrates a software application flow diagram for the software application shown in FIG. 1, according to an exemplary aspect.

[0040] FIG. 3 is a schematic illustration of the software application of the analyte monitoring system shown in FIG. 1, according to an exemplary aspect.

[0041] FIGS. 4A and 4B are schematic illustrations of a state diagram and corresponding display notification(s) for a conditional logic state of the software application shown in FIG. 3, according to an exemplary aspect.

[0042] FIGS. 5A and 5B are schematic illustrations of a state diagram and corresponding display notification(s) for a conditional logic state of the software application shown in FIG. 3, according to an exemplary aspect.

[0043] FIGS. 6A and 6B are schematic illustrations of a state diagram and corresponding display notification(s) for a conditional logic state of the software application shown in FIG. 3, according to an exemplary aspect.

[0044] FIGS. 7A and 7B are schematic illustrations of a state diagram and corresponding display notification(s) for a conditional logic state of the software application shown in FIG. 3, according to an exemplary aspect.

[0045] FIGS. 8A and 8B are schematic illustrations of a state diagram and corresponding display notification(s) for a conditional logic state of the software application shown in FIG. 3, according to an exemplary aspect.

[0046] FIGS. 9A and 9B are schematic illustrations of a state diagram and corresponding display notification(s) for a conditional logic state of the software application shown in FIG. 3, according to an exemplary aspect.

[0047] FIGS. 10A and 10B are schematic illustrations of a state diagram and corresponding display notification(s) for a conditional logic state of the software application shown in FIG. 3, according to an exemplary aspect.

[0048] FIG. 11 is a schematic illustration of a dose guidance system of the software application shown in FIG. 3, according to an exemplary aspect.

[0049] FIG. 12 is a schematic illustration of a glycemic response model of the software application shown in FIG. 3, according to an exemplary aspect.

[0050] FIG. 13 is an exemplary display of ketone metrics.

[0051] The features and exemplary aspects of the aspects will become more apparent from the detailed description set forth below when taken in conjunction with the drawings, in which like reference characters identify corresponding elements throughout. In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. Additionally, generally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears. Unless otherwise indicated, the drawings provided throughout the disclosure should not be interpreted as to-scale drawings.

DETAILED DESCRIPTION

[0052] This specification discloses one or more aspects that incorporate the features of this present invention. The disclosed aspect(s) merely exemplify the present invention. The scope of the invention is not limited to the disclosed aspect(s). The present invention is defined by the claims appended hereto.

[0053] The aspect(s) described, and references in the specification to “one aspect,” “an aspect,” “an example aspect,” “an exemplary aspect,” etc., indicate that the aspect(s) described can include a particular feature, structure, or characteristic, but every aspect may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring

to the same aspect. Further, when a particular feature, structure, or characteristic is described in connection with an aspect, it is understood that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other aspects whether or not explicitly described.

[0054] Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “on,” “upper” and the like, can be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus can be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein can likewise be interpreted accordingly.

[0055] The term “about” or “substantially” or “approximately” as used herein means the value of a given quantity that can vary based on a particular technology. Based on the particular technology, the term “about” or “substantially” or “approximately” can indicate a value of a given quantity that varies within, for example, 0.1–10% of the value (e.g., $\pm 0.1\%$, $\pm 1\%$, $\pm 2\%$, $\pm 5\%$, or $\pm 10\%$ of the value).

[0056] Numerical values, including endpoints of ranges, can be expressed herein as approximations preceded by the term “about,” “substantially,” “approximately,” or the like. In such cases, other aspects include the particular numerical values. Regardless of whether a numerical value is expressed as an approximation, two aspects are included in this disclosure: one expressed as an approximation, and another not expressed as an approximation. It will be further understood that an endpoint of each range is significant both in relation to another endpoint, and independently of another endpoint.

[0057] Aspects of the disclosure may be implemented in hardware, firmware, software, or any combination thereof. Aspects of the disclosure may also be implemented as instructions stored on a machine-readable medium (e.g., memory), which may be read and executed by one or more processors. A machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computing device). For example, a machine-readable medium may include read only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustic, or other forms of propagated signals (e.g., carrier waves, infrared signals, digital signals,

etc.), and other. Further, firmware, software, routines, and/or instructions may be described herein as performing certain actions. However, it should be appreciated that such descriptions are merely for convenience and that such actions in fact result from computing devices, processors, controllers, or other devices executing the firmware, software, routines, instructions, etc.

[0058] The term “glucose-ketone condition” or “glucose-ketone conditions” as used herein indicates an adverse patient condition or conditions dependent upon glucose and/or ketone levels, for example, hypoglycemia, hyperglycemia, DKA, euDKA, ketosis, ketonuria, epilepsy, headache, fatigue, insomnia, nausea, or any other adverse condition.

[0059] The term “contextual data” as used herein indicates data received from a user based on context related to a detected condition, for example, but not limited to, discomfort data (e.g., levels of physical discomfort, levels of mental discomfort, headache, fatigue, emergency services, etc.), illness data (e.g., cancer, nausea, viral, bacterial, etc.), dietary data (e.g., fasting, keto diet, no carbs, etc.), activity data (e.g., strenuous activity, running, etc.), contributing factors data (e.g., genetics, obesity, etc.), medication data (e.g., SGLT-2 inhibitors, statins, etc.), insulin delivery data (e.g., pump fault, insulin suspension, etc.), frequency data (e.g., number of times the condition occurs in a time period), or any other data based on context.

[0060] The term “recommendation” as used herein indicates a recommendation to a user based on a detected condition, for example, but not limited to, adjusting medication delivery (e.g., insulin, SGLT-2 inhibitors, etc.), behavioral changes, food intake (e.g., carb amounts, etc.), hydration, seeking emergency services, monitoring one or more analytes (e.g., glucose, ketones, etc.), or any other recommendation based on one or more analyte levels being in certain ranges.

[0061] Exemplary Analyte Monitoring System

[0062] As discussed above, the detection and/or monitoring of analyte levels (e.g., glucose, ketones, lactate, oxygen, hemoglobin A1C, etc.) can be vitally important to the health of a person with diabetes (PwD). Patients suffering from diabetes mellitus can experience complications including loss of consciousness, cardiovascular disease, retinopathy, neuropathy, and/or nephropathy. DKA is a potentially life-threatening complication of diabetes mellitus. DKA is an adverse condition concerning to diabetes patients, which can result in hospitalization or even death. DKA results from a shortage of insulin, which in response the body produces acidic ketone bodies. DKA is associated with high ketone levels that are caused by insufficient glucose uptake in insulin-

dependent cells, evident from long durations of high glucose levels. Glucose uptake insufficiency resulting in DKA can be caused by insufficient insulin levels in the patient or high levels of insulin resistance, for example, caused by illness. In this case, the glucose levels may be in the target range or below. Generally, DKA happens with type-1 diabetes patients, but it can occur under certain circumstances with other diabetes types.

[0063] PwDs are generally required to monitor their glucose levels to ensure they are maintained within a clinically safe range, and may also use this information to determine if and/or when insulin is needed to reduce glucose levels in their bodies or when additional glucose is needed to raise glucose levels in their bodies. A number of systems allow individuals to monitor their blood glucose, for example, CGM. Some of these systems include electrochemical biosensors, including those that use a glucose sensor adapted to be positioned in vivo, for example, with complete or partial insertion into a subcutaneous or transcutaneous site, within the body for continuous in vivo monitoring of glucose levels of bodily fluids (e.g., blood, interstitial fluid) of the site.

[0064] Growing clinical data demonstrates a strong correlation between the frequency of glucose monitoring and glycemic control. Despite such correlation, many PwDs do not monitor their glucose levels as frequently as they should due to a combination of factors including inconvenience, testing discretion, pain associated with glucose testing, and/or cost. For patients that rely on the administration of medications (e.g., insulin, SGLT-2 inhibitors, etc.) to treat or manage diabetes, it is desirable to have systems, devices, and/or methods that can integrate glucose data with insulin dosing data and provide more actionable insights to patients, caregivers, HCPs, and/or PCPs.

[0065] SGLT-2 inhibitors, also called flozins, are a class of medications that modulate SGLT proteins in the nephrons of the kidney, thereby inhibiting reabsorption of glucose and lowering blood sugar. This effectively lowers the renal glucose clearance threshold, which makes it more difficult to achieve high sugar concentration in blood. As a result, SGLT-2 inhibitors can increase the risk of DKA, and specifically can cause euDKA, where production of ketone bodies is increased to make up for the lower glucose availability. EuDKA causes high ketone levels with normal glucose levels. Patients (e.g., type-1 diabetes patients) that use certain medications (e.g., SGLT-2 inhibitors) are at risk of euDKA.

[0066] SGLT-2 inhibitors are diabetes medications that can help reduce glucose variability around meal times and are designated for use with type-2 diabetes patients. SGLT-2 inhibitors can

also help type-1 diabetes patients in managing their glucose levels. However, there is a concern in using SGLT-2 inhibitors for type-1 diabetes patients because of the possibility of causing high ketone levels and DKA, with normal levels of glucose, referred to herein as euDKA. For people with type-1 diabetes, sotagliflozin, an SGLT-1 and SGLT-2 inhibitor, is currently the only medication containing an SGLT-2 inhibitor approved by the European Medicines Agency (European Union). Currently, no SGLT-2 inhibitors medications are approved by the FDA for type-1 diabetes patients. Therefore, continuous ketone monitoring can be an important component in managing type-2 diabetes with SGLT-2 inhibitors, and potentially mitigate the risk of euDKA in type-1 diabetes patients taking SGLT-2 inhibitors medications. For this discussion, it is to be understood that any medication that can lower the renal glucose clearance threshold in addition to SGLT-2 inhibitors can generate this euDKA risk or ketoacidosis in general.

[0067] Continuous monitoring of additional analytes (e.g., ketones, lactic acid, lactate, alcohol, etc.) can be utilized to detect an adverse condition in real-time, for example, an adverse glucose-ketone condition (e.g., euDKA). However, although discrete ketone test strips, along with CGM, are available, these systems are impractical and/or insufficient for continuous monitoring of ketones. Further, it is complex and difficult for a patient to correctly interpret additional analyte levels (e.g., ketones, lactate, lactic acid, alcohol) and determine the appropriate action, requiring the patient to contact a HCP for proper interpretation and guidance.

[0068] Treatment for euDKA generally includes administering insulin and offsetting any unwanted glucose lowering impact (e.g., due to the insulin) by consuming carbohydrates. However, it can be confusing to a patient when they should perform this treatment and when they should seek emergency medical intervention. For example, it can be confusing to the patient to know what to do when their ketone levels are elevated, but not high enough to represent DKA, and their glucose levels are in the normal range or lower. In addition, the patient's HCP would benefit from contextual information before and after an elevated or high ketone episode, in order to better understand the cause of the patient's condition and, if needed, help mitigate the condition.

[0069] Aspects of analyte monitoring apparatuses, systems, and methods as discussed below can provide a software application that can detect current or impending adverse conditions (e.g., glucose-ketone conditions), provide custom notifications (e.g., warnings, recommendations, guidance, etc.) to the patient to act, prompt the patient for additional information relevant to the detected condition, continuously monitor glucose and ketone levels in real-time, control insulin

delivery based on ketone level, and mitigate the risk of euDKA. Further, aspects of analyte monitoring apparatuses, systems, and methods as discussed below can deliver guidance to a patient at appropriate times and capture additional information (e.g., contextual data) about the patient's condition at a moment when the patient will remember it.

[0070] FIG. 1 illustrates analyte monitoring system 100 with software application 300, according to exemplary aspects. Analyte monitoring system 100 can be configured to measure first and second analytes of a patient (e.g., glucose and ketones), detect current or impending adverse conditions (e.g., glucose-ketone conditions), provide custom notifications (e.g., warnings, recommendations, guidance) to the patient to act, and/or prompt the patient for additional information relevant to the detected condition. Analyte monitoring system 100 can be further configured to continuously monitor first and second analyte levels (e.g., glucose and ketone levels) in real-time, control insulin delivery based on ketone level, and/or mitigate the risk of euDKA. Although analyte monitoring system 100 is shown in FIG. 1 as a stand-alone apparatus and/or system, aspects of this disclosure can be used with other apparatuses, systems, and/or methods, for example, analyte monitoring system flow diagram 200A, software application flow diagram 200B, software application 300, and/or state diagrams 400A–1000A and corresponding display notification(s) 400B–1000B.

[0071] As shown in FIG. 1, analyte monitoring system 100 can include analyte measurement system 110, remote server 180, insulin delivery system 190, and/or software application 300. Analyte measurement system 110 can be configured to measure (e.g., via on body unit 120) a first analyte (e.g., glucose) and a second analyte (e.g., ketones, lactate, lactic acid, alcohol) of a patient. Analyte measurement system 110 can be further configured to display and/or notify (e.g., via display device 130) a patient of measured levels of first analyte (e.g., glucose) and second analyte (e.g., ketones, lactate, lactic acid, alcohol). As shown in FIG. 1, analyte measurement system 110 can include on body unit (OBU) 120, insertion device 128, and display device 130.

[0072] OBU 120 can be configured to measure and communicate data of a first analyte (e.g., glucose) and a second analyte (e.g., ketone, lactate, lactic acid, alcohol) of a patient. OBU 120 can be further configured to communicate data (e.g., sensor data 312) from analyte sensor 122 to one or more components of analyte monitoring system 100 (e.g., display device 130, remote server 180, insulin delivery system 190, software application 300, etc.). As shown in FIG. 1, OBU 120

can include analyte sensor 122, on body electronics 124, on body housing 125, and/or adhesive layer 126.

[0073] Analyte sensor 122 can be configured to measure a first analyte (e.g., glucose) and a second analyte (e.g., ketone, lactate, lactic acid, alcohol) of a patient. Analyte sensor 122 can be further configured to continuously measure (e.g., in vivo) in real-time a concentration of one or more analytes (e.g., first analyte 123a, second analyte 123b, etc.) of a patient. As shown in FIG. 1, analyte sensor 122 can detect first analyte 123a (e.g., glucose) and second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol). In some aspects, a portion of analyte sensor 122 (e.g., distal portion) can be positioned in vivo through a skin surface of a patient (e.g., transcutaneously) and in fluid contact with bodily fluids (e.g., blood, interstitial fluid, etc.) of the patient. In some aspects, analyte sensor 122 can be insertable into a body of a patient (e.g., vein, artery, skin, etc.) containing an analyte. In some aspects, analyte sensor 122 can include CGM to continuously and automatically track glucose levels (e.g., first analyte level 314a). In some aspects, analyte sensor 122 can include continuous ketone monitoring to continuously and automatically track ketone levels (e.g., second analyte level 314b).

[0074] In some aspects, for example, as shown in FIG. 1, analyte sensor 122 can include a single (dual) analyte sensor to measure first and second analytes 123a, 123b (e.g., simultaneously). In some aspects, analyte sensor 122 can include two separate analyte sensors to measure first and second analytes 123a, 123b (e.g., a CGM sensor and a separate continuous ketone monitoring sensor). In some aspects, first analyte 123a can be glucose and second analyte 123b can be ketones. In some aspects, analyte sensor 122 can measure and retrieve glucose and ketone levels in real-time (e.g., about 1-60 seconds) for continuous analyte (e.g., glucose-ketone) monitoring. In some aspects, analyte sensor 122 can measure and retrieve glucose and ketone levels in near real-time (e.g., about 1-15 minutes) for discrete analyte (e.g., glucose-ketone) monitoring. Exemplary analyte monitoring systems are described in US 2018/0256103, US 2024/0033427, US 2022/0056500, US 2020/0237275, US 2022/0386910, US 2021/0190719, US 2021/0219885, US 2022/0186278, US 2022/0233116, US 2022/0186277, US 2022/0202327, US 2022/0386910, all of which are hereby incorporated by reference in their entireties for all purposes.

[0075] In some aspects, analyte sensor 122 can automatically and/or continuously monitor one or more analyte levels (e.g., first analyte 123a, second analyte 123b, etc.) in vivo, for example, glucose and ketones of a patient, over a predetermined time interval (e.g., sensor lifetime) or given

sensing period (e.g., 1 day, 3 days, 7 days, 14 days, 30 days, at least 1 day, at least 3 days, at least 1-3 days, at least 7 days, at least 10 days, optionally 1-10 days, at least 14 days, at least 3-14 days, at least 30 days, etc.). In some aspects, analyte sensor 122 can be coupled (e.g., electronically) to on body electronics 124 to process information obtained from analyte sensor 122 (e.g., sensor data 312). In some aspects, analyte sensor 122 can be in communication (e.g., wired, wirelessly) with on body electronics 124.

[0076] In some aspects, analyte sensor 122 can measure one or more analytes. For example, analyte sensor 122 can measure one or more metabolic analytes (e.g., glucose, ketones, lactate, lactic acid, oxygen, hemoglobin A1C, lactone, lactose, galactose, vitamin C, glucuronate, glycogen, mannose, phosphate, bisphosphate, fructose, glyceraldehyde, glycerol, triglycerides, sorbitol, phosphoglucono, phosphogluconate, xylulose, ribose, bile, cysteine, serine, homoserine, pyruvate, phenylpyruvate, glutamate, glycine, taurine, threonine, methionine, ethanol, acetone, acetate, oxaloacetate, alanine, phenylalanine, aspartate, asparagine, alcohol, cholesterol, vitamin D, progesterone, testosterone, estrogen, squalene, insulin, hydroxybutyrate, leucine, isoleucine, malonyl, malonate, glucagon, epinephrine, norepinephrine, palmitate, lysine, eicosanoids, melanin, dopamine, tyrosine, tryptophan, niacin, melatonin, serotonin, citrate, isocitrate, valine, porphyrins, histidine, urocanate, histamine, glutamine, proline, creatine, putrescine, spermidine, spermine, arginine, ornithine, citrulline, fumarate, succinate, argininosuccinate, succinyl, ketoglutarate, aconitate, glyoxylate, caffeine, sugars, carbs, etc.). In some aspects, analyte sensor 122 can measure one or more analytes simultaneously with one or more corresponding electrochemical biosensors for each different analyte measured.

[0077] On body electronics 124 can be configured to process signals from analyte sensor 122. On body electronics 124 can be further configured to communicate data (e.g., sensor data 312) from analyte sensor 122 to one or more external devices (e.g., software application 300, display device 130, remote server 180, etc.). On body electronics 124 can be further configured to wirelessly communicate (e.g., WiFi, Bluetooth, Internet, etc.) analyte related data (e.g., first analyte 123a and/or second analyte 123b). As shown in FIG. 1, on body electronics 124 can be operatively (e.g., electrically) coupled to analyte sensor 122 and wirelessly coupled to display device 130 and software application 300.

[0078] In some aspects, on body electronics 124 can include a printed circuit board (PCB) for connection to various components (e.g., analyte sensor 122, processor, ASIC, wireless transceiver,

wireless transmitter, controller, memory, etc.). In some aspects, on body electronics 124 can store (e.g., via memory) historical analyte related data (e.g., first analyte 123a and/or second analyte 123b). In some aspects, on body electronics 124 can be configured to store some or all of analyte related data (e.g., sensor data 312) from analyte sensor 122 in a memory, for example, during a sensing period (e.g., 1 day, 3 days, 7 days, 14 days, 30 days, etc.). In some aspects, on body electronics 124 can include one or more processors and/or control logic configured to determine (e.g., via software programs and/or algorithms) future and/or anticipated analyte levels based on analyte related data (e.g., sensor data 312) from analyte sensor 122. In some aspects, on body electronics 124 can include one or more processors and/or control logic configured to determine (e.g., via software programs and/or algorithms) current analyte levels (e.g., first analyte level 314a, second analyte level 314b, etc.), rates of change of analyte levels (e.g., first analyte ROC 316a, second analyte ROC 316b, etc.), rates of acceleration of analyte levels (e.g., rates of first and second analyte ROCs 316a, 316b), and/or analyte trend information (e.g., trend display 144), and/or analyte fluctuation levels (e.g., standard deviation, etc.).

[0079] In some aspects, on body electronics 124 can be configured to periodically send (broadcast) analyte related data (e.g., sensor data 312) to one or more external devices (e.g., software application 300, display device 130, remote server 180, etc.), for example, without receiving a command or request from the external device. In some aspects, on body electronics 124 can be configured to send (broadcast) real-time data associated with monitored analyte levels (e.g., first analyte 123a and/or second analyte 123b) from analyte sensor 122 to one or more external devices (e.g., software application 300, display device 130, remote server 180, etc.), for example, when the external device is within a communication range of the data broadcast from OBU 120.

[0080] In some aspects, on body electronics 124 can be configured to wirelessly transmit stored analyte related data (e.g., first analyte 123a and/or second analyte 123b) during a monitoring time period to one or more external devices (e.g., software application 300, display device 130, remote server 180, etc.). In some aspects, analyte related data (e.g., sensor data 312) sent from on body electronics 124 can be stored in one or more memory units (e.g., permanently, temporarily), for example, memory units on one or more external devices (e.g., software application 300, display device 130, remote server 180, etc.). In some aspects, display device 130 can be configured as a

data conduit to pass data received from on body electronics 124 (e.g., sensor data 312) to one or more external devices (e.g., software application 300, remote server 180, etc.).

[0081] On body housing 125 can be configured to provide an interior compartment for a portion of analyte sensor 122 (e.g., proximal portion) and on body electronics 124. As shown in FIG. 1, on body housing 125 can include analyte sensor 122 and on body electronic 124 and be coupled to adhesive layer 126. In some aspects, on body housing 125 can include a sealed housing (e.g., hermetically sealed biocompatible housing). Adhesive layer 126 can be configured to attach OBU 120 to a skin surface of a patient. As shown in FIG. 1, adhesive layer 126 can be coupled to on body housing 125 to securely position a portion of analyte sensor 122 (e.g., distal portion) to a skin surface. In some aspects, adhesive layer 126 can provide a terminal seal of insertion device 128.

[0082] Insertion device 128 can be configured to position a portion of analyte sensor 122 (e.g., distal portion) through a skin surface of a patient (e.g., in vivo) and in fluid contact with bodily fluids (e.g., blood, interstitial fluid) of the patient. Insertion device 128 can be further configured to adhere OBU 120 onto the skin surface of a patient. As shown in FIG. 1, insertion device 128 can be configured to hold OBU 120 and, when operated, position a portion of analyte sensor 122 in vivo through a skin surface of a patient and in fluid contact with bodily fluids (e.g., blood, interstitial fluid), and secure OBU 120 to the skin surface. In some aspects, OBU 120 can be sealed within insertion device 128 prior to use.

[0083] Display device 130 can be configured to output (e.g. display) information to the patient. Display device 130 can be further configured to provide custom notifications (e.g., warnings, recommendations, guidance, etc.) to the patient (e.g., via software application 300). Display device 130 can be further configured to provide custom prompts to the patient for additional information (e.g., via software application 300). As shown in FIG. 1, display device 130 can be operatively (e.g., wirelessly) coupled to OBU 120, remote server 180, and/or software application 300. In some aspects, display device 130 can include a handheld computer (e.g., smartphone, cell phone, mobile phone, PDA, smart watch, etc.), personal computer, laptop computer, or any other portable communication device.

[0084] In some aspects, a default home screen of display device 130 can be changed (e.g., glucose display to ketone display, etc.) based on a detected condition, for example, the condition detected via software application 300. In some aspects, the default home screen of display device 130 can include glucose data (e.g., glucose level, glucose rate of change, glucose trend, etc.), but

when ketone levels are elevated the default home screen of display device 130 can change to display ketone data (e.g., ketone level, ketone rate of change, ketone trend, etc.) or change so that both glucose and ketone data are displayed. As shown in FIG. 1, display device 130 can include housing 132, input component 134, data communication port 136, and/or display 140.

[0085] Input component 134 can be configured to control operation of display device 130. Input component 134 can be further configured to input data and/or commands to display device 130. As shown in FIG. 1, input component 134 can interact with display device 130 to control operation of display device 130 (e.g., respond to a notification and/or prompt). In some aspects, input component 134 can include a button, an actuator, a switch, a jog wheel, a touch screen, a microphone, a camera, a combination thereof, or a similar input element. For example, input component 134 can be a touch screen or touch sensitive element of display 140. In some aspects, input component 134 can include audio commands, for example, recognized via a microphone of display device 130. In some aspects, input component 134 can include predetermined motion and/or gesture commands, for example, recognized via a camera of display device 130.

[0086] Data communication port 136 can be configured to communicate data with one or more external devices (e.g., OBU 120, software application 300, remote server 180, blood glucose reader, blood ketone reader, etc.). As shown in FIG. 1, data communication port 136 can be operatively coupled to housing 132 of display device 130. In some aspects, data communication port 136 can include wireless data communication (e.g., WiFi, Bluetooth, cloud computing, Internet, etc.). In some aspects, data communication port 136 can include a wireless transceiver, wireless transmitter, and/or wireless receiver. In some aspects, data communication port 136 can include wired data communication (e.g., USB port, mini-USB port, serial port, Ethernet port, Internet port, etc.).

[0087] In some aspects, data communication port 136 can be configured to receive data from an in vitro test strip (e.g. having a fluid sample thereon) based on in vitro measurements (e.g., blood glucose measurement, blood ketone measurement, etc.), for example, from a blood glucose reader and/or a blood ketone reader. In some aspects, data communication port 136 can be configured to receive data from an in vitro glucose test strip based on in vitro blood glucose measurements via a blood glucose reader. In some aspects, data communication port 136 can be configured to receive data from an in vitro ketone test strip based on in vitro blood ketone measurements via a blood ketone reader. In some aspects, data communication port 136 can be configured to receive data

from an in vitro test strip based on in vitro fluid measurements for a variety of analytes (e.g., glucose, ketones, lactate, lactic acid, oxygen, hemoglobin A1C, alcohol, etc.), via a fluid analyte reader.

[0088] Display 140 can be configured to display a variety of information—some or all of which can be displayed at the same time or at different times. Display 140 can be further configured to output alarms, notifications (e.g., warnings, recommendations, guidance, etc.), prompts, first analyte 123a (e.g., glucose) levels, second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol) levels, or a combination thereof, which can be visual, audio, tactile, or a combination thereof. As shown in FIG. 1, display 140 can include, but is not limited to, graphical display 142, trend display 144, numerical display 146, menu input 148, time display 150, graph input 152, connectivity display 154, alarm display 156, date display 158, sensor calibration display 160, and/or battery display 162.

[0089] In some aspects, a default home screen for display 140 can display glucose data, for example, the glucose level (e.g., first analyte level 314a, numerical display 146), rate of change of glucose level (e.g., first analyte ROC 316a, trend display 144), and a glucose plot (e.g., graphical display 142). In some aspects, a default home screen for display 140 can display ketone data, for example, ketone level (e.g., second analyte level 314b, numerical display 146), rate of change of ketone level (e.g., second analyte ROC 316b, trend display 144), and a ketone plot (e.g., graphical display 142).

[0090] In some aspects, a default home screen for display 140 can display glucose data and can include an indication of a ketone range (e.g., second analyte level 314b, etc.). In some aspects, a default home screen for display 140 can display glucose data and omit any indication of ketones, for example, if ketone levels are within a normal range (e.g., about 0.5-1.5 mmol/L) or close to a baseline value (e.g., about 0.5 mmol/L).

[0091] In some aspects, a default home screen for display 140 can display glucose data and can include an indication of ketones, for example, if ketone levels are elevated within a moderate range (e.g., about 1.0-3.0 mmol/L) or a high range (e.g., above 3.0 mmol/L). For example, display 140 can display ketone level (e.g., second analyte level 314b, numerical display 146) and/or (optionally) display rate of change of ketone level (e.g., second analyte ROC 316b, trend display 144), which can be calculated based on a predetermined sensing period (e.g., 15 minutes, 30 minutes, 60 minutes, etc.).

[0092] In some aspects, when ketone levels are elevated (e.g., above 1.0 mmol/L), a default home screen for display 140 can change to be ketone centric rather than glucose centric. For example, display 140 can display ketone data, for example, ketone level (e.g., second analyte level 314b, numerical display 146), rate of change of ketone level (e.g., second analyte ROC 316b, trend display 144), and/or a ketone plot (e.g., graphical display 142), and display 140 can indicate if there is a low glucose level (e.g., below 70 mg/dL).

[0093] In some aspects, when ketone levels are elevated (e.g., above 1.0 mmol/L), a default glucose time series plot (e.g., graphical display 142) of display 140 can automatically be replaced by a ketone time series plot (e.g., graphical display 142). In some aspects, a ketone time series plot (e.g., graphical display 142) can utilize a different time range (X-axis) than a default glucose time series plot (e.g., graphical display 142), for example, 24 hours for the ketone plot rather than 8 hours for the glucose plot. In some aspects, a glucose time series plot (e.g., graphical display 142) and a ketone time series plot (e.g., graphical display 142) can be collocated (e.g., side-by-side) on display 140. For example, the glucose axis can be displayed on the left Y-axis and the ketone axis can be displayed on the right Y-axis, and the time scale (X-axis) can switch accordingly (e.g., switch to 24 hours). In some aspects, display 140 can include user interface means (e.g., input component 134, user interface subsystem 344 of software application 300) to switch or toggle between glucose focused information and ketone focused information.

[0094] In some embodiments, the system can monitor only a single analyte, e.g., a ketone body, and a default home screen 1800 of display device 130 can only display ketone metrics, as seen in FIG. 13. Alternatively, multiple analytes can be monitored and a single analyte, e.g., ketone, can be displayed. The ketone metrics can include a current (or most recently measured) ketone level 146, a ketone trend arrow 144, a ketone graph 242, and a time above a threshold level 250. The current ketone level 146 and trend arrow 144 can be displayed in a banner on the GUI 18800. The current ketone level 146 can be displayed differently depending on the value of the current ketone level 146. For certain ranges, a numerical value of the ketone level will not be displayed. When the current ketone level 146 is less than the low threshold, a statement can be displayed instead of a numerical value of the ketone level. For example, if the low threshold is 0.5 mmol/L, the current ketone level can be displayed as "< 0.5" when the ketone level is less than 0.5 mmol/L. Similarly, when the current ketone level 146 is above a high threshold, a different statement can be displayed instead of the numerical value of the ketone level. For example, if the high threshold is 3.0

mmol/L, the current ketone level can be displayed as “>3.0” when the ketone level is greater than 3.0 mmol/L. If the current ketone level 146 is at or above the low threshold and at or below the high threshold, the current ketone level can be displayed as the numerical value of the ketone level. For example, a ketone level of 1.7 mmol/L can be displayed as 1.7 mmol/L.

[0095] The ketone graph 242 can display current and historic ketone levels or can only display historic ketone levels. If a user drags their finger along the ketone trace 244, the ketone numerical levels can be displayed along the graph. For example, the numerical value of the ketone levels can be displayed in a flag 248 above the ketone trace 244 along with a time corresponding to the measured ketone level. The indication of the ketone level in the flag can be differ depending on the value of the ketone level, and whether the ketone level is below the low threshold, at or above the low threshold and at or below the high threshold, or above the high threshold, as described above with respect to the current ketone level 146. The ketone graph 242 can include lines marking various levels, e.g., a line delineating 1.0 mmol/L 242 and a different line for 1.5 mmol/L 244 to highlight for the user when their measured levels are above these various thresholds at a glance. The ketone graph 242 can display ketone levels within a range, and ketone levels at or above or at or below the upper and lower limits of the range can be displayed as a line or as a break in the trace. For example, the range can be from 0.5 mmol/L to 3 mmol/L. Ketone levels below 0.5 mmol/L can be displayed as a line at 0.5 mmol/L and ketone values above mmol/L can be displayed as a line at 3.0 mmol/L or as a break in the ketone trace. In some embodiments, a time difference between the current or real-time ketone level 146 and ketone levels displayed on the graph. For example, the current or real-time ketone level 146 can be updated every minute, while the graph 242 can be updated every 5 minutes, alternatively every 10 minutes, alternatively every 15 minutes, alternatively every 20 minutes, and alternatively every 30 minutes. The time above the threshold level 250 can be the number of hours that the user has had measured ketone levels above the threshold level for the day 220 being displayed, e.g., the current day. The threshold level can be about 0.5 mmol/L, alternatively about 0.6 mmol/L, alternatively about 1.0 mmol/L, alternatively about 1.5 mmol/L. GUI 1800 can also include a link to a live screen 222 and a link to settings 224.

[0096] GUI 1800 can also include indicators regarding the status of the sensor. The indicators can include an icon 230 indicating the status of the sensor along with information 232 regarding the status of the biosensor. In some embodiments, the icon 230 can also include a progress

indicator that indicates the time remaining for the biosensor to be ready. The icon 230 can include a graphic highlighting the time remaining until the biosensor is active. The graphic can include a radiating circle of dots, which can be animated. The icon 230 can include a progress indicator that can be a bar having a colored portion or can be a colored portion along the perimeter of a circle, where the colored portion is proportional to the amount of time remaining before the sensor is active, e.g., a total perimeter of a circle can be equivalent to 60 minutes and a colored portion of the perimeter can be proportional to the amount of time remaining under an hour for the sensor to be active. The information 232 can include text indicating that the sensor is “READY IN XX,” wherein XX can be displayed in minutes and seconds. For example, the banner 1002 can display “READY IN 55:10” where the sensor will be active in 55 minutes and 10 seconds. Or the information 232 can include text indicating that the sensor is currently active and display “LIVE.”

[0097] Graphical display 142 can be configured to provide a graphical plot (e.g., time series plot) of first analyte 123a (e.g., glucose) and/or second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol) from analyte sensor 122. As shown in FIG. 1, graphical display 142 can include a plot of first analyte 123a (e.g., glucose) over time. In some aspects, graphical display 142 can include a plot of second analyte 123b (e.g., ketones, lactate, lactic acid, alcohol) over time. In some aspects, graphical display 142 can include one or more plots of corresponding one or more analytes. For example, graphical display 142 can include a glucose time series plot (e.g., based on first analyte 123a) and a ketone time series plot (e.g., based on second analyte 123b) collocated on display 140. In some aspects, graphical display 142 can include important markers, for example, meals, exercise, sleep, heart rate, blood pressure, etc.

[0098] Trend display 144 can be configured to indicate a rate of change (ROC) of first analyte 123a (e.g., glucose) and/or second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol). As shown in FIG. 1, trend display 144 can include an arrow (trend) indicating a ROC of first analyte 123a (e.g., glucose). In some aspects, trend display 144 can indicate a magnitude and a direction of any ongoing trend, for example, a ROC of first analyte 123a (e.g., glucose). In some aspects, trend display 144 can include a ROC of first analyte 123a (e.g., glucose). In some aspects, trend display 144 can include a ROC of second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol). In some aspects, trend display 144 can include one or more arrows (trends) of corresponding one or more analytes. For example, trend display 144 can include a glucose arrow (e.g., first analyte ROC 316a) and a ketone arrow (e.g., second analyte ROC 316b) collocated (e.g., side-by-side) on

display 140. In some aspects, trend display 144 can indicate a rate of a ROC of first analyte 123a (e.g., glucose) and/or second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol).

[0099] Numerical display 146 can be configured to provide monitored levels of first analyte 123a (e.g., glucose) and/or second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol). As shown in FIG. 1, numerical display 146 can indicate a current value of an analyte, for example, first analyte 123a (e.g., glucose). In some aspects, numerical display 146 can include a numerical level of first analyte 123a (e.g., glucose), for example, in units of mg/dL. In some aspects, numerical display 146 can include a numerical level of second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol), for example, in units of mmol/L. In some aspects, numerical display 146 can include one or more current values (numerical levels) of corresponding one or more analytes. For example, numerical display 146 can include a glucose level (e.g., first analyte level 314a) and a ketone level (e.g., second analyte level 314b) collocated (e.g., side-by-side) on display 140.

[0100] Menu input 148 can be configured to control operation of display device 130. Menu input 148 can be further configured to provide access to additional menus of display 140 (e.g., changing display settings, etc.). As shown in FIG. 1, menu input 148 can be located on display 140. In some aspects, menu input 148 can be a touch screen button or touch sensitive element of display 140. In some aspects, menu input 148 can include a touch screen, gesture recognition, command recognition (e.g., audio, visual), or other suitable input element. In some aspects, menu input 148 can be configured to change display configurations of display 140, for example, changing default home screen configurations.

[0101] Time display 150 can be configured to provide time of day information. Connectivity display 154 can be configured to indicate wireless communication connections with other devices (e.g., OBU 120, remote server 180, insulin delivery system 190, software application 300, etc.). Date display 158 can be configured to provide date information. Battery display 162 can be configured to indicate (e.g., graphically) a condition of the battery (e.g., rechargeable, disposable) of display device 130. As shown in FIG. 1, time display 150, connectivity display 154, date display 158, and battery display 162 can be located along a perimeter panel of display 140.

[0102] Graph input 152 can be configured to control operation of graphical display 142. In some aspects, graph input 152 can be further configured to provide access to additional menus of graphical display 142 (e.g., changing graphical display settings, etc.). As shown in FIG. 1, graph input 152 can be a touch screen button or touch sensitive element of display 140. In some aspects,

graph input 152 can include a touch screen, gesture recognition, command recognition (e.g., audio, visual), or other suitable input element. In some aspects, graph input 152 can be configured to change display configurations of graphical display 142, for example, changing a time scale (X-axis) of graphical display 142.

[0103] Alarm display 156 can be configured to indicate a status of an alarm state. As shown in FIG. 1, alarm display 156 can be located above graphical display 142 and indicate when particular alarms have been triggered (e.g., via software application 300). In some aspects, alarm display 156 can indicate one or more particular alarms, for example, low glucose threshold alarm (e.g., about 70 mg/dL), moderate glucose threshold alarm (e.g., about 110 mg/dL), high glucose threshold alarm (e.g., about 180 mg/dL), low ketone threshold alarm (e.g., about 0.5 mmol/L), moderate ketone threshold alarm (e.g., about 1.0 mmol/L), high ketone threshold alarm (e.g., about 3.0 mmol/L), etc. In some aspects, alarm display 156 can indicate one or more particular alarms dependent upon first analyte 123a (e.g., glucose) and second analyte 123b (e.g., ketone, lactate, lactic acid, alcohol) levels, for example, as shown in FIGS. 8A, 9A, and 10A, an alarm can be triggered if ketone level is below a high ketone threshold (e.g., about 3.0 mmol/L) and above a low ketone threshold (e.g., about 0.5 mmol/L) and glucose level is above a high glucose threshold (e.g., about 180 mg/dL), an alarm can be triggered if ketone level is below a high ketone threshold (e.g., about 3.0 mmol/L) and above a low ketone threshold (e.g., about 0.5 mmol/L) and glucose level is below a high glucose threshold (e.g., about 180 mg/dL) and above a low glucose threshold (e.g., about 70 mg/dL), or an alarm can be triggered if ketone level is below a high ketone threshold (e.g., about 3.0 mmol/L) and above a low ketone threshold (e.g., about 0.5 mmol/L) and glucose level is below a low glucose threshold (e.g., about 70 mg/dL), respectively. In some aspects, graphical display 142 can also display alarm icons in conjunction with alarm display 156. In some aspects, particular alarms and/or alarm icons can be changed (e.g., customized) by a user or HCP, for example, based on changes to predetermined settings 332 (e.g., thresholds 334) of software application 300.

[0104] The alarm notifications described in various embodiments herein can include toast alerts, banner alerts, lock screen alerts, slide-up notifications, or any other alert well known in mobile application design. The notification can include a tactile component, such as a vibration. The notification can include an audible component, such as a sound like a beep.

[0105] Sensor calibration display 160 can be configured to indicate when calibration of analyte sensor 122 is necessary. As shown in FIG. 1, sensor calibration display 160 can be located on an upper panel of display 140. In some aspects, sensor calibration display 160 can provide periodic, routine, and/or predetermined calibration events based on a status of analyte sensor 122. In some aspects, sensor calibration display 160 can notify a user when calibration or replacement of analyte sensor 122 is needed, for example, display 140 (e.g., graphical display 142, alarm display 156) can also display calibration alarm icons in conjunction with sensor calibration display 160. In some aspects, sensor calibration can be omitted (e.g., calibration not needed).

[0106] Remote server 180 can be configured to provide data management, data analysis, and/or data communication with one or more components of analyte monitoring system 100 (e.g., OBU 120, display device 130, insulin delivery system 190, software application 300, etc.). Remote server 180 can be configured to support display device 130 and/or software application 300. As shown in FIG. 1, remote server 180 can be operatively (e.g., wirelessly) coupled to display device 130 and software application 300. In some aspects, remote server 180 can include a personal computer (e.g., smartphone), a laptop computer, an external server, a server terminal, a cloud server, a web server, or other suitable server that provides functionality for other programs and/or devices.

[0107] In some aspects, remote server 180 can be connected to a wireless network (e.g., Internet), a local area network (LAN), a wide area network (WAN), or any other data network for unidirectional or bidirectional data communication between one or more components of analyte monitoring system 100 (e.g., OBU 120, display device 130, insulin delivery system 190, software application 300, etc.). In some aspects, remote server 180 can provide new software and/or software updates (e.g., versions, patches, fixes, updates, upgrades, etc.) to one or more components of analyte monitoring system 100 (e.g., OBU 120, display device 130, insulin delivery system 190, software application 300, etc.). In some aspects, all of software application 300 can be contained in remote server 180. In some aspects, some or part of software application 300 can be contained in remote server 180, for example, supporting processing, communication, and/or reporting functionalities of software application 300.

[0108] Insulin delivery system (IDS) 190 can be configured to provide insulin to a patient. IDS 190 can be further configured to adjust a rate of insulin to the patient (e.g., in response to CGM value and trend). As shown in FIG. 1, IDS 190 can be operatively coupled to software application

300. In some aspects, IDS 190 can be an automated insulin delivery (AID) system. In some aspects, IDS 190 can include an insulin pump, an infusion set, a CGM (e.g., analyte sensor 122), a controller (e.g., algorithm to calculate and dynamically adjust insulin delivery based on CGM value and trend), or a combination thereof. In some aspects, IDS 190 can include an insulin pen (e.g., a smart insulin pen).

[0109] In some aspects, IDS 190 can be operatively coupled to OBU 120, display device 130, remote server 180, and/or software application 300, for example, to form a closed loop system for automatic delivery of insulin to the patient in appropriate amounts and at appropriate times. In some aspects, software application 300 can control an amount of insulin delivered by IDS 190 based on a detected condition. In some aspects, software application 300 can control insulin delivery from IDS 190 based on ketone levels (e.g., second analyte level 314b). For example, software application 300 can be configured to continue insulin delivery from IDS 190 if the ketone level is above a high ketone threshold (e.g., above about 3.0 mmol/L).

[0110] In some aspects, when ketone levels are elevated (e.g., above 3.0 mmol/L), software application 300 can override a default or planned insulin delivery from IDS 190. For example, IDS 190 may normally stop or decrease insulin delivery if only considering glucose levels (e.g., normal glucose level, glucose error detected, glucose fault detected, etc.), but software application 300 can control IDS 190 to continue insulin delivery if the ketone level is high (e.g., above 3.0 mmol/L), thereby mitigating euDKA.

[0111] Software application 300 can be configured to retrieve sensor data (e.g., sensor data 312) of first and second analyte levels (e.g., first and second analyte levels 314a, 314b). Software application 300 can be further configured to detect a condition (e.g., condition detection 320) based on sensor data (e.g., sensor data 312) from analyte sensor 122. Software application 300 can be further configured to provide a notification (e.g., notification 352) to the patient based on the condition (e.g., conditional logic states 10, 20, 30, 40, 50, 60, 70). As shown in FIG. 1, software application 300 can be operatively coupled to OBU 120, display device 130, remote server 180, and IDS 190. In some aspects, software application 300 can include one or more processors (e.g., processor, controller, microprocessor, microcontroller, ASIC, etc.). In some aspects, software application 300 can include and/or be coupled to a memory storing instructions, for example, instructions that when executed cause one or more processors of software application 300 to, including but not limited to, retrieve sensor data of first and second analyte levels, detect a

condition based on the sensor data, provide a notification to the patient based on the condition, prompt the patient to enter contextual data (e.g., based on the condition), save a record of the detected condition along with the contextual data, and/or generate a report including detected conditions and associated contextual data.

[0112] In some aspects, software application 300 can be part of analyte measurement system 110. For example, software application 300 can be part of display device 130. In some aspects, software application 300 can include a mobile application (app). For example, software application 300 can be part of display device 130 (e.g., in a mobile app). In some aspects, remote server 180 can be configured to support all or part of software application 300. In some aspects, software application 300 can all be contained in a patient mobile application (app). In some aspects, some or part of software application 300 can be contained in remote server 180 (e.g., web-server, cloud server, etc.) that supports software application 300. For example, remote server 180 can support processing, communication, and/or reporting functionalities of software application 300. In some aspects, software application 300 can include an application programming interface (API) for two or more computer programs to communicate with each other (e.g., conditional logic system 310, settings system 330, notification system 350, dose control system 370, etc.).

[0113] In some aspects, software application 300 can include a mobile app based system that detects conditions where actions should be taken, provides guidance to the patient, and provides a means to record important contextual data concurrent with the detected condition, for example, contextual data that will be helpful to a HCP to know later when advising the patient on how to avoid the detected condition in the future. In some aspects, processing and functionality required for software application 300 can all be contained in a mobile app. In some aspects, some or part of software application 300 (e.g., mobile app) can be contained in remote server 180 that supports software application 300, for example, remote server 180 can support the mobile app with processing, communication hub, and reporting functionality. In some aspects, functionality described herein for software application 300 includes functionality on the mobile app, remote server 180, or both, noting that all or some functionality can be in either or both. In some aspects, reference to software application 300 described herein implies both a mobile app and a web server (e.g., remote server 180) supporting the mobile app.

[0114] In some aspects, software application 300 (e.g., mobile app) can retrieve continuous glucose sensor data (e.g., first analyte level 314a) and continuous ketone sensor data (e.g., second

analyte level 314b) in real-time (e.g., continuous monitoring 318). In some aspects, these data may come from two separate analyte sensors, or a dual analyte sensor (e.g., analyte sensor 122) where a single sensor provides data for both analytes. In some aspects, software application 300 can retrieve episodic discrete glucose measurements and/or discrete ketone measurements. In some aspects, software application 300 can retrieve various combinations of discrete and continuous analyte measurements. In some aspects, software application 300 can include a mechanism (e.g., algorithm) to retrieve discrete analyte measurements during a sensing period or a situation when continuous analyte measurements are not available.

[0115] In some aspects, software application 300 (e.g., mobile app) can retrieve and process sensor data from OBU 120 in near real-time (e.g., about 1-15 minutes), for example, every minute, every 5 minutes, every 10 minutes, every 15 minutes, etc. In some aspects, software application 300 (e.g., mobile app) can retrieve and process sensor data from OBU 120 in real-time (e.g., about 1-60 seconds), for example, every second, every 5 seconds, every 10 seconds, every 15 seconds, every 30 seconds, every 60 seconds, etc.

[0116] In some aspects, software application 300 (e.g., mobile app) can retrieve and process (e.g., in real-time) first analyte 123a (e.g., glucose) and/or second analyte 123b (e.g., ketones, lactate, lactic acid, alcohol) data at different frequencies (e.g., every minute for glucose and every 15 minutes for ketones). In some aspects, software application 300 (e.g., mobile app) can retrieve and process (e.g., in real-time) first analyte 123a (e.g., glucose) and second analyte 123b (e.g., ketones, lactate, lactic acid, alcohol) data at different periods for different times of the day. For example, depending on a likelihood that alcohol will be consumed (e.g., higher likelihood at night than in the morning), real-time processing of software application 300 can be suspended or limited to a low periodicity (e.g., measurements every hour) during the morning hours when alcohol consumption is less likely, for example, to minimize unnecessary power consumption and/or communication bandwidth of software application 300.

[0117] In some aspects, software application 300 (e.g., mobile app) can be utilized for cases where high ketones may be a concern. For example, software application 300 can be utilized for type-1 diabetes patients taking SGLT-2 inhibitors, for example, to mitigate the risk of euDKA. In some aspects, software application 300 (e.g., mobile app) can be operatively coupled (e.g., wirelessly) to an insulin delivery or insulin guidance system (e.g., IDS 190) of a patient to automatically determine if the patient is suffering from some form of insulin resistance (e.g.,

caused by illness, excess weight, metabolic syndrome, stroke, high triglycerides, etc.). For example, software application 300 can determine if insulin correction doses do not seem to be lowering glucose levels.

[0117] Alternative Alarm embodiments

[0118] In some embodiments, the analyte monitoring system may provide an alarm display when certain conditions are met. For example, alarm thresholds may be set to warn a user that their ketone levels are rising in an effort to prevent possible DKA or euglycemic DKA. The alarm display can be configured to display or output an alarm if a ketone level is above a first threshold (e.g., about 1.0 mmol/L). An additional alarm may be displayed or outputted if a ketone level is above a second threshold that is higher than the first threshold (e.g., about 1.5 mmol/L). An additional alarm may be displayed or outputted if a ketone level is above a third threshold that is higher than the second threshold (e.g., about 2.0 mmol/L). An additional alarm may be displayed or outputted if a ketone level is above a fourth threshold that is higher than the third threshold (e.g., about 3.0 mmol/L). If an alarm is triggered, the notification associated with the alarm may include the numerical value of the ketone level triggering the alarm, e.g., ketone level: 2.4 mmol/L. In some embodiments, the alarm may be outputted periodically while the ketone level is above at least one threshold. For example, the alarm may be outputted every 5 minutes, alternatively every 10 minutes, alternatively every 15 minutes, alternatively every 30 minutes. In some embodiments, the periodicity of the alarm may depend on the ketone level or the ketone threshold that was triggered. For example, an interval of an alarm resulting from a ketone level above the first threshold may be larger than an interval of an alarm resulting from a ketone level above the second higher threshold. For example, if the thresholds are 1.0 mmol/L and 1.5 mmol/L, the interval for the alarm if a ketone level is 1.4 mmol/L may be every 15 minutes, while the interval for the alarm if a ketone level is 2.6 mmol/L may be every 5 minutes.

[0119] The alarm notifications described in various embodiments herein may include toast alerts, banner alerts, lock screen alerts, slide-up notifications, or any other alert well known in mobile application design. The notification may include a tactile component, such as a vibration. The notification may include an audible component, such as a sound like a beep.

[0120] Exemplary Flow Diagrams

[0121] FIG. 2A illustrates analyte monitoring system flow diagram 200A for analyte monitoring system 100 shown in FIG. 1, according to an exemplary aspect. Analyte monitoring system flow diagram 200A can be configured to measure first and second analytes of a patient (e.g., glucose and ketones), detect current or impending adverse conditions (e.g., glucose-ketone conditions), provide custom notifications (e.g., warnings, recommendations, guidance) to the patient to act, and/or prompt the patient for additional information relevant to the detected condition. It is to be appreciated that not all steps in FIG. 2A are needed to perform the disclosure provided herein. Further, some of the steps may be performed simultaneously, sequentially, and/or in a different order than shown in FIG. 2A. Analyte monitoring system flow diagram 200A shall be described with reference to FIGS. 1, 3, and 4A–10B. However, analyte monitoring system flow diagram 200A is not limited to those example aspects. Although analyte monitoring system flow diagram 200A is shown in FIG. 2A as a stand-alone method, aspects of this disclosure can be used with other apparatuses, systems, and/or methods, for example, analyte monitoring system 100, software application flow diagram 200B, and/or software application 300. In some aspects, analyte monitoring system flow diagram 200A can be implemented by analyte monitoring system 100 and/or software application 300 shown in FIG. 1.

[0122] In step 202A, as shown in the example of FIGS. 1 and 3, first analyte 123a and second analyte 123b of a patient can be measured with analyte measurement system 110. In some aspects, analyte measurement system 110 can include analyte sensor 122 and display device 130. In some aspects, measuring can include continuously measuring first and second analytes 123a, 123b in real-time (e.g., about 1-60 seconds). In some aspects, measuring can include measuring first and second analytes 123a, 123b in near real-time (e.g., about 1-15 minutes). In some aspects, measuring can include continuous ketone monitoring to account for dynamic effects of ketones, for example, on glycemic response.

[0123] In step 204A, as shown in the example of FIGS. 1 and 3, sensor data 312 of first and second analyte levels 314a, 314b can be retrieved from OBU 120 with software application 300. In some aspects, software application 300 (e.g., mobile app) can be operatively coupled (e.g., wirelessly) to analyte measurement system 110. In some aspects, software application 300 can retrieve and process sensor data 312 in real-time (e.g., every second, every 5 seconds, every 10 seconds, every 15 seconds, every 30 seconds, every 60 seconds, etc.). In some aspects, software

application 300 can retrieve and process sensor data 312 in near real-time (e.g., every minute, every 5 minutes, every 10 minutes, every 15 minutes, etc.).

[0124] In step 206A, as shown in the example of FIGS. 1, 3, 4A–10B, a condition (e.g., condition detection 320) can be detected based on sensor data 312. In some aspects, software application 300 can detect current or impending adverse conditions (e.g., glucose-ketone conditions) at all times or at appropriate times of the day (e.g., low periodicity during morning hours). In some aspects, detecting can include utilizing conditional logic (e.g., conditional logic system 310) based on predetermined settings (e.g., predetermined settings 332). In some aspects, predetermined settings can include first and second threshold values of first analyte 123a (e.g., first analyte thresholds 336) and third and fourth threshold values of second analyte 123b (e.g., second analyte thresholds 338). In some aspects, detecting can utilize default or editable thresholds (e.g., glucose and ketone thresholds) to provide notifications (e.g., warning, recommendation, guidance, prompts) associated with each conditional logic state defined by the thresholds.

[0125] In step 208A, as shown in the example of FIGS. 1, 3, 4A–10B, a notification (e.g., notification 352) can be provided to the patient based on the condition. In some aspects, providing the notification can include providing a warning (e.g., warning 354), a recommendation (e.g., 356), or a combination thereof. In some aspects, providing the notification can include providing custom notifications (e.g., warnings, recommendations, guidance) to the patient to act based on detected current or impending adverse conditions (e.g., glucose-ketone conditions).

[0126] In step 210A, optionally, as shown in the example of FIGS. 1, 3, 4A–10B, a prompt (e.g., prompt 358) can be provided to the patient to request additional information (e.g., contextual data 362) regarding the condition. In some aspects, providing the prompt can be provided at appropriate times relevant to the detected condition (e.g., immediately after the condition is detected). In some aspects, providing the prompt can include capturing additional information (e.g., contextual data 362) about the patient's condition at a moment when the patient will remember it, for example, to assist a clinician or HCP determine an underlying cause of the condition. In some aspects, contextual data (e.g., contextual data 362) can be associated with the particular condition that is detected, for example, hyperglycemia can be associated with a first contextual data whereas hypoglycemia can be associated with a second contextual data. In some aspects, contextual data (e.g., contextual data 362) can be entered or selected from, for example, a drop-down list (e.g., prompt 508b shown in FIG. 5B), as free-form text via an input of display device 130 (e.g., input

component 134), as free-form audio via an input of display device 130 (e.g., input component 134).

[0127] FIG. 2B illustrates software application flow diagram 200B for software application 300 shown in FIGS. 1 and 3, according to an exemplary aspect. Software application flow diagram 200B can be configured to detect current or impending adverse conditions (e.g., glucose-ketone conditions) and provide custom notifications (e.g., warnings, recommendations, guidance) to the patient to act at appropriate times. It is to be appreciated that not all steps in FIG. 2B are needed to perform the disclosure provided herein. Further, some of the steps may be performed simultaneously, sequentially, and/or in a different order than shown in FIG. 2B. Software application flow diagram 200B shall be described with reference to FIGS. 1, 3, and 4A–10B. However, software application flow diagram 200B is not limited to those example aspects. Although software application flow diagram 200B is shown in FIG. 2B as a stand-alone method, aspects of this disclosure can be used with other apparatuses, systems, and/or methods, for example, analyte monitoring system 100, analyte monitoring system flow diagram 200A, and/or software application 300. In some aspects, software application flow diagram 200B can be implemented by software application 300 shown in FIGS. 1 and 3.

[0128] In step 202B, as shown in the example of FIGS. 1 and 3, sensor data 312 of first and second analyte levels 314a, 314b of a patient can be retrieved. In some aspects, software application 300 can retrieve and process sensor data 312 in real-time (e.g., every second, every 5 seconds, every 10 seconds, every 15 seconds, every 30 seconds, every 60 seconds, etc.). In some aspects, software application 300 can retrieve and process sensor data 312 in near real-time (e.g., every minute, every 5 minutes, every 10 minutes, every 15 minutes, etc.).

[0129] In step 204B, as shown in the example of FIGS. 1 and 3, first and second analyte levels 314a, 314b can be determined to be below or above predetermined settings (e.g., predetermined settings 332, thresholds 334). In some aspects, predetermined settings (e.g., predetermined settings 332) can include one or more default thresholds (e.g., thresholds 334). In some aspects, thresholds 334 can include first analyte threshold(s) 336 (e.g., one or more glucose thresholds) and second analyte threshold(s) 338 (e.g., one or more ketone thresholds). In some aspects, first analyte thresholds 336 can include, but are not limited to, low glucose threshold (e.g., about 70 mg/dL), moderate glucose threshold (e.g., about 110 mg/dL), and/or high glucose threshold (e.g., about 180 mg/dL). In some aspects, second analyte thresholds 338 can include, but are not limited to, low

ketone threshold (e.g., about 0.5 mmol/L), moderate ketone threshold (e.g., about 1.0 mmol/L), and/or high ketone threshold (e.g., about 3.0 mmol/L). In some aspects, predetermined settings (e.g., predetermined settings 332, thresholds 334, adjustment settings 340, etc.) can extend to any number of predetermined settings and/or thresholds, for example, with distinct text (e.g., notification 352, warning 354, recommendation 356, prompt 358) associate with each conditional logic state defined by the predetermined settings and/or thresholds.

[0130] In step 206B, as shown in the example of FIGS. 1, 3, 4A–10B, a condition (e.g., condition detection 320) can be detected based on whether first and second analyte levels 314a, 314b are below or above the predetermined settings. In some aspects, detecting can include utilizing conditional logic (e.g., conditional logic system 310) based on predetermined settings (e.g., predetermined settings 332). In some aspects, predetermined settings can include first and second threshold values of first analyte 123a (e.g., first analyte thresholds 336) and third and fourth threshold values of second analyte 123b (e.g., second analyte thresholds 338). In some aspects, first analyte thresholds 336 can include, but are not limited to, low glucose threshold (e.g., about 70 mg/dL), moderate glucose threshold (e.g., about 110 mg/dL), and/or high glucose threshold (e.g., about 180 mg/dL), for example, first threshold value of first analyte 123a can be a low glucose threshold (e.g., about 70 mg/dL, at least 70 mg/dL, about 60 mg/dL to about 80 mg/dL, etc.) and second threshold value of first analyte 123a can be a high glucose threshold (e.g., about 180 mg/dL, at least 180 mg/dL, about 140 mg/dL to about 220 mg/dL, etc.). In some aspects, second analyte thresholds 338 can include, but are not limited to, low ketone threshold (e.g., about 0.5 mmol/L), moderate ketone threshold (e.g., about 1.0 mmol/L), and/or high ketone threshold (e.g., about 3.0 mmol/L), for example, third threshold value of second analyte 123b can be a moderate ketone threshold (e.g., about 1.0 mmol/L, at least 1.0 mmol/L, about 0.8 mmol/L to about 1.2 mmol/L, etc.) and fourth threshold value of second analyte 123b can be a high ketone threshold (e.g., about 3.0 mmol/L, at least 3.0 mmol/L, about 2.5 mmol/L to about 3.5 mmol/L, etc.). In some aspects, detecting can utilize default or editable thresholds (e.g., glucose and ketone thresholds) to provide notifications (e.g., warning, recommendation, guidance, prompts) associated with each conditional logic state defined by the thresholds.

[0131] In step 208B, as shown in the example of FIGS. 1, 3, 4A–10B, a notification (e.g., notification 352) can be provided to the patient based on the condition. In some aspects, providing the notification can include providing a warning (e.g., warning 354), a recommendation (e.g., 356),

or a combination thereof. In some aspects, providing the notification can include providing custom notifications (e.g., warnings, recommendations, guidance) to the patient to act based on detected current or impending adverse conditions (e.g., glucose-ketone conditions).

[0132] In step 210B, optionally, as shown in the example of FIGS. 1, 3, 4A–10B, a prompt (e.g., prompt 358) can be provided to the patient to retrieve additional information (e.g., contextual data 362) regarding the condition. In some aspects, the additional information (e.g., contextual data 362) can include contextual information related to a detected condition to assist a clinician or HCP determine an underlying cause of the condition, for example, the contextual information can include patient discomfort (e.g., a numerical discomfort level of the patient, patient selection from a list of discomfort levels/descriptions, etc.), contributing factors, medications taken, frequency of the condition (e.g., number of times the conditions occurs in at least one of 1 hour, 6 hours, 12 hours, a day, a week, a month, etc.), whether the patient received emergency medical services, etc. In some aspects, providing the prompt can be provided at appropriate times relevant to the detected condition (e.g., immediately after the condition is detected). In some aspects, providing the prompt can include capturing additional information (e.g., contextual data 362) about the patient's condition at a moment when the patient will remember it, for example, to assist a clinician or HCP determine an underlying cause of the condition.

[0133] Exemplary Software Application

[0134] FIG. 3 illustrates software application 300, according to exemplary aspects. Software application 300 can be configured to measure sensor data 312 of analyte sensor 122 including first and second analyte levels 314a, 314b of a patient (e.g., glucose and ketones). Software application 300 can be further configured to detect current or impending adverse conditions (e.g., glucose-ketone conditions) and provide custom notifications (e.g., warnings, recommendations, guidance) to the patient to act. Software application 300 can be further configured to prompt the patient for additional information relevant to the detected condition. Software application 300 can be further configured to continuously monitor first and second analyte levels 314a, 314b (e.g., glucose and ketone levels) in real-time. Software application 300 can be further configured to control insulin delivery (e.g., via IDS 190) based on ketone level and mitigate the risk of euDKA. Although software application 300 is shown in FIG. 3 as a stand-alone apparatus and/or system, aspects of this disclosure can be used with other apparatuses, systems, and/or methods, for example, analyte

monitoring system 100, analyte measurement system 110, analyte monitoring system flow diagram 200A, software application flow diagram 200B, and/or state diagrams 400A–1000A and corresponding display notification(s) 400B–1000B.

[0135] As shown in FIG. 3, software application 300 can include conditional logic system 310, settings system 330, notification system 350, and/or dose control system 370. Conditional logic system 310 can be configured to retrieve sensor data 312 (e.g., first and second analytes 123a, 123b) from analyte sensor 122 of analyte measurement system 110. Conditional logic system 310 can be further configured to determine if first and second analyte levels 314a, 314b of sensor data 312 are below or above predetermined settings 332. Conditional logic system 310 can be further configured to detect a condition (e.g., condition detection 320) based on whether first and second analyte levels 314a, 314b of sensor data 312 are below or above predetermined settings 332.

[0136] Conditional logic system 310 can be operatively coupled to settings system 330, notification system 350, and/or dose control system 370. As shown in FIG. 3, conditional logic system 310 can include sensor data 312, continuous monitoring 318, condition detection 320, error detection 322, and/or predictive model 324.

[0137] Sensor data 312 can be configured to measure one or more analytes of a patient (e.g., glucose and ketones). As shown in FIG. 3, sensor data 312 can include first analyte level 314a (e.g., glucose level), second analyte level 314b (e.g., ketone level), first analyte rate of change (ROC) 316a (e.g., glucose ROC), and/or second analyte ROC 316b (e.g., ketone ROC). In some aspects, first analyte level 314a (e.g., glucose level) and/or second analyte level 314b (e.g., ketone level) can be estimated in a variety of ways. For example, first and second analyte levels 314a, 314b can each be estimated by an average (mean), median, mode, weighted average, geometric average, moving average, weighted median, weighted mode, mid-range, or a combination thereof. In some aspects, predetermined settings 332 can depend on first analyte level 314a (e.g., glucose level) and/or second analyte level 314b (e.g., ketone level).

[0138] In some aspects, first analyte ROC 316a (e.g., glucose ROC) and/or second analyte ROC 316b (e.g., ketone ROC) can be estimated in a variety of ways. For example, second analyte ROC 316b (e.g., ketone ROC) can be estimated by determining a slope of the most recent 15 minute window of second analyte level 314b (e.g., ketone level). In some aspects, predetermined settings 332 can additionally depend on first analyte ROC 316a (e.g., glucose ROC) and/or second analyte ROC 316b (e.g., ketone ROC). For example, a moderate ketone range can be defined as second

analyte level 314b (e.g., ketone level) greater than about 1.0 mmol/L or, alternatively, as second analyte level 314b (e.g., ketone level) greater than about 0.5 mmol/L and second analyte ROC 316b (e.g., ketone ROC) greater than about 0.3 mmol/L/hr calculated based on the recent data (e.g. the past 15 minutes, half hour, 2 hours, or other pre-determined duration).

[0139] Continuous monitoring 318 can be configured to continuously monitor one or more analytes of a patient (e.g., glucose and ketones). As shown in FIG. 3, continuous monitoring 318 can continuously monitor sensor data 312 from analyte sensor 122, for example, CGM and continuous ketone monitoring. In some aspects, continuous monitoring 318 can monitor sensor data 312 in real-time (e.g., every second, every 5 seconds, every 10 seconds, every 15 seconds, every 30 seconds, every 60 seconds, etc.). In some aspects, continuous monitoring 318 can include continuous ketone monitoring (e.g., second analyte level 314b) to account for dynamic effects of ketones, for example, on glycemic response. In some aspects, continuous monitoring 318 can monitor sensor data 312 in near real-time (e.g., every minute, every 5 minutes, every 10 minutes, every 15 minutes, etc.).

[0140] Condition detection 320 can be configured to detect a condition (e.g., conditional logic state) based on whether sensor data 312 (e.g., first and second analyte levels 314a, 314b) is below or above predetermined settings 332. As shown in FIG. 3, condition detection 320 can receive sensor data 312 and compare sensor data 312 to predetermined settings 332 (e.g., thresholds 334). In some aspects, condition detection 320 can detect a conditional logic state based on predetermined settings (e.g., predetermined settings 332, thresholds 334). For example, as shown in state diagrams 400A–1000A of FIGS. 4A, 5A, 6A, 7A, 8A, 9A, and 10A, condition detection 320 can detect conditional logic states 10, 20, 30, 40, 50, 60, 70 based on a comparison of sensor data 312 to predetermined settings 332 (e.g., thresholds 334), respectively.

[0141] In some aspects, condition detection 320 can detect a high ketone condition (e.g., rising ketone levels), a moderate ketone condition (e.g., dropping ketone levels), a low ketone condition (e.g., rapidly recovered ketone levels), a low ketone condition (e.g., recovered ketone levels), a moderate ketone and high glucose condition (e.g., moderate ketone-high glucose condition), a moderate ketone and moderate glucose condition (e.g., moderate ketone-moderate glucose condition), and/or a moderate ketone and low glucose condition (e.g., moderate ketone-low glucose condition).

[0142] In some aspects, condition detection 320 can detect a high ketone condition (rising ketone levels). For example, as shown in FIG. 4A, condition detection 320 can detect first conditional logic state 10, for example, a high ketone condition when the ketone level transitions from below to above a high ketone threshold (e.g., about 3.0 mmol/L). In some aspects, condition detection 320 can detect a moderate ketone condition (dropping ketone levels). For example, as shown in FIG. 5A, condition detection 320 can detect second conditional logic state 20, for example, a moderate ketone condition when the ketone level transitions from above to below a high ketone threshold (e.g., about 3.0 mmol/L).

[0143] In some aspects, condition detection 320 can detect a low ketone condition (rapidly recovered ketone levels). For example, as shown in FIG. 6A, condition detection 320 can detect third conditional logic state 30, for example, a low ketone condition when the ketone level transitions from above a high ketone threshold (e.g., about 3.0 mmol/L) to below a low ketone threshold (e.g., about 0.5 mmol/L). In some aspects, condition detection 320 can detect a low ketone condition (recovered ketone levels). For example, as shown in FIG. 7A, condition detection 320 can detect fourth conditional logic state 40, for example, a low ketone condition when the ketone level transitions from above a moderate ketone threshold (e.g., about 1.0 mmol/L) to below a low ketone threshold (e.g., about 0.5 mmol/L).

[0144] In some aspects, condition detection 320 can detect a moderate ketone and high glucose condition (moderate ketone-high glucose condition). For example, as shown in FIG. 8A, condition detection 320 can detect fifth conditional logic state 50, for example, a moderate ketone-high glucose condition when the ketone level is below a high ketone threshold (e.g., about 3.0 mmol/L) and above a low ketone threshold (e.g., about 0.5 mmol/L) and the glucose level is above a high glucose threshold (e.g., about 180 mg/dL).

[0145] In some aspects, condition detection 320 can detect a moderate ketone and moderate glucose condition (moderate ketone-moderate glucose condition). For example, as shown in FIG. 9A, condition detection 320 can detect sixth conditional logic state 60, for example, a moderate ketone-moderate glucose condition when the ketone level is below a high ketone threshold (e.g., about 3.0 mmol/L) and above a low ketone threshold (e.g., about 0.5 mmol/L) and the glucose level is below a high glucose threshold (e.g., about 180 mg/dL) and above a low glucose threshold (e.g., about 70 mg/dL).

[0146] In some aspects, condition detection 320 can detect a moderate ketone and low glucose condition (moderate ketone-low glucose condition). For example, as shown in FIG. 10A, condition detection 320 can detect seventh conditional logic state 70, for example, a moderate ketone-low glucose condition when the ketone level is below a high ketone threshold (e.g., about 3.0 mmol/L) and above a low ketone threshold (e.g., about 0.5 mmol/L) and the glucose level is below a low glucose threshold (e.g., about 70 mg/dL).

[0147] In some aspects, condition detection 320 (e.g., condition logic) can incorporate hysteresis (e.g., lag behind changes of an effect causing a measured value), for example, to reduce erratic changes in a detected condition due to a noisy ROC estimation. For example, if the detected condition is determined to be a moderate ketone level (e.g., about 1.0 mmol/L) based on second analyte ROC 316b (e.g., ketone ROC), for example, being greater than about 0.3 mmol/L/hr, then to return to a low ketone level (e.g., about 0.5 mmol/L) the condition logic can be defined as second analyte level 314b (e.g., ketone level) less than about 1.0 mmol/L and second analyte ROC 316b (e.g., ketone ROC) less than about 0 mmol/L/hr.

[0148] Error detection 322 can be configured to detect errors in sensor data 312. As shown in FIG. 3, error detection 322 can receive sensor data 312 and perform error detection. In some aspects, error detection 322 can periodically perform quality checks of sensor data 312, for example, error detection, potential error detection, error verification, and/or error correction. In some aspects, error detection 322 can perform error correction for detected errors in sensor data 312. In some aspects, error detection 322 can be configured to increase a signal-to-noise ratio (SNR) of sensor data 312, for example, by utilizing one or more error detection techniques (e.g., parity check, cyclic redundancy check, forward error correction, automatic repeat request, error-correcting code, etc.).

[0149] In some aspects, error detection 322 can be configured to determine an erroneous reading based on first analyte level 314a (e.g., glucose level) and/or second analyte level 314b (e.g., ketone level). For example, error detection 322 can detect an indication of euDKA or an erroneous glucose reading (e.g., low glucose when glucose levels are actually high), based on high ketone levels and low or normal glucose levels. In some aspects, error detection 322 can utilize second analyte level 314b (e.g., ketone level) to detect errors in first analyte level 314a (e.g., glucose level). In some aspects, error detection 322 can utilize first analyte level 314a (e.g., glucose level) to detect errors in second analyte level 314b (e.g., ketone level).

[0150] In some aspects, software application 300 can detect an indication of euDKA or an erroneous glucose reading (e.g., error detection 322), based on high ketone levels and low or normal glucose levels, and notify the patient accordingly to take appropriate action, for example, taking a blood glucose measurement (e.g., blood glucose test strip) to confirm the glucose level. In some aspects, software application 300 can detect an indication of euDKA or an erroneous ketone reading (e.g., error detection 322), based on high ketone levels and low or normal glucose levels, and notify the patient accordingly to take appropriate action, for example, taking a blood ketone measurement (e.g., blood ketone test strip) to confirm the ketone level.

[0151] In some aspects, analyte sensor 122 can include a ketone sensor and a glucose sensor, and the ketone sensor can be used to detect faults in the glucose sensor and the glucose sensor can be used to detect faults in the ketone sensor. In some aspects, error detection 322 can detect a glucose sensor fault based on high glucose levels and low ketone levels, for example, if software application 300 detects that insulin was recently delivered (e.g., via IDS 190). In some aspects, error detection 322 can detect a ketone sensor fault based on high glucose levels and low ketone levels, for example, if software application 300 detects that insulin was not recently delivered (e.g., via IDS 190).

[0152] In some aspects, software application 300 can be operatively coupled (e.g., wirelessly) to an insulin delivery system (e.g., IDS 190) or an insulin pen (e.g., smart insulin pen) and insulin delivery data can be analyzed by error detection 322, for example, to confirm a glucose sensor (e.g., analyte sensor 122) is functioning properly. In some aspects, software application 300 can include a predictive model (e.g., predictive model 324) that can include insulin delivery data and/or insulin dose guidance information, for example, whether a patient sought guidance for a prandial insulin dose or a high-glucose corrective dose. In some aspects, the predictive model (e.g., predictive model 324) can consider the time of day, for example, overnight (e.g., between 11:00 PM and 7:00 AM), since ketones tend to rise overnight due to the patient fasting. In some aspects, error detection 322 can detect a glucose sensor fault, for example, if the measured glucose level (e.g., first analyte level 314a) is substantially different than a predicted glucose level (e.g., via predictive model 324). In some aspects, error detection 322 can detect a ketone sensor fault, for example, if the measured ketone level (e.g., second analyte level 314b) is substantially different than a predicted ketone level (e.g., via predictive model 324).

[0153] In some aspects, error detection 322 can utilize analyte sensor 122 (e.g., dual glucose-ketone sensor, separate glucose and ketone sensors) to detect issues with pump delivery of insulin (e.g., infusion set occlusion) or issues with pen delivery of insulin. For example, error detection 322 can detect a fault with the insulin delivery (e.g., where some or all of the insulin was not delivered to the patient) based on high ketone levels and high glucose levels and insulin delivery (e.g., via IDS 190) was recorded. In some aspects, if a fault with insulin delivery is detected (e.g., error detection 322), software application 300 can provide direction and instruction to the patient (e.g., notification 352) to check the functionality of the insulin delivery system (e.g., IDS 190).

[0154] In some aspects, error detection 322 can detect a fault with pump occlusion based on ketone levels rising faster than glucose levels. For example, error detection 322 can detect that second analyte ROC 316b (e.g., ketone ROC) has exceeded a predetermined ketone ROC threshold (e.g., about 0.3 mmol/L/hr), followed by first analyte ROC 316a (e.g., glucose ROC) exceeding a predetermined glucose ROC threshold (e.g., about 35 mg/dL/hr). In some aspects, error detection 322 can detect an anomalous sensor attenuation (e.g., decrease in sensitivity) based on high ketone levels concurrent with low glucose levels. For example, the anomalous sensor attenuation can occur at the beginning of the sensor lifetime, late in the sensor lifetime, or during the sensor lifetime (e.g., when the patient applies pressure to the sensor).

[0155] In some aspects, in an AID system (or similarly with a manually injected insulin system), if the glucose sensor is erroneously reading low (e.g., analyte sensor 122), then insulin delivery may be low or suspended (e.g., IDS 190). For example, glucose levels may be rising undetected but ketone levels may rise and be detected. In some aspects, software application 300, based on high ketone levels (e.g., error detection 322), can notify the patient (e.g., notification 352) to confirm their glucose level with a blood glucose test strip.

[0156] In some aspects, error detection 322 can detect anomalous events and/or sensor errors retrospectively. For example, an elevated ketone level concurrent with low insulin delivery data when detected can cause a report generation process (e.g., reporting 364) to exclude from the report calculations of the glucose data prior to (e.g., about 4 hours) and up to the point when the detected condition is no longer indicated.

[0157] In some aspects, error detection 322 and/or IDS 190 can include a pump-occlusion detection subsystem. For example, the pump-occlusion detection subsystem can include a method for measuring the tubing pressure during insulin delivery (e.g., pressure sensor). In some aspects,

error detection 322 can notify the patient of a possible pump-occlusion, for example, if the tubing pressure during insulin delivery exceeds a tubing pressure threshold. In some aspects, error detection 322 can detect a possible pump-occlusion based on first analyte level 314a (e.g., glucose) and/or second analyte level 314b (e.g., ketone, lactate, lactic acid, alcohol) and adjust one or more parameters of a pump-occlusion detection subsystem, for example, lowering a tubing pressure threshold used to detect occlusion. In some aspects, parameters and outputs of both a glucose-ketone based occlusion detector (e.g., error detection 322) and a pressure based occlusion detector (e.g., IDS 190) can be integrated together in any number of ways to provide a more reliable occlusion detection method, for example, in a predictive model (e.g., predictive model 324). In some aspects, if both error detection 322 and IDS 190 are deemed to generate high certainty detection that contradict each other, an alternate response can be triggered. For example, if the error detection 322 inferred an unreasonable increase in ketone levels for the given glucose history, that increase in ketone levels can be associated with pump-occlusion, but if the IDS 190 does not indicate anomalous pressure, then it is possible that a different kind of condition, for example, but not limited to, lipohypertrophy (e.g., build-up of scar tissue due to repeated injections), is reducing the efficacy of the infusion site. In this case, a prompt to reapply the canula into a new infusion site may be triggered.

[0158] Predictive model 324 can be configured to analyze sensor data 312 and other information (e.g., insulin delivery data) to model a patient's future conditions. As shown in FIG. 3, predictive model 324 can include population model 326 and/or predictive algorithm 328. In some aspects, predictive model 324 can be based on one or more parameters, including but not limited to, sensor data 312, first analyte level 314a (e.g., glucose), second analyte level 314b (e.g., ketones, lactate, lactic acid, alcohol), first analyte ROC 316a (e.g., glucose ROC), second analyte ROC 316b (e.g., ketone ROC), insulin delivery data (e.g., IDS 190), continuous monitoring 318, condition detection 320, error detection 322, predetermined settings 332, adjustment settings 340, contextual data 362, etc.

[0159] In some aspects, software application 300 can be configured to perform analytics (e.g., periodically) of sensor data 312 to determine a baseline level of first analyte level 314a (e.g., glucose) and/or a baseline level of second analyte level 314b (e.g., ketone, lactate, lactic acid, alcohol). For example, a baseline of second analyte level 314b (e.g., ketone, lactate, lactic acid, alcohol) can be determined by calculating the median of the ketone level, assuming that the patient

is at a baseline level for most of the time sampled for the calculation. In some aspects, software application 300 can be configured to perform periodic analysis of sensor data 312. For example, software application 300 can determine a baseline level of first analyte level 314a (e.g., glucose) and/or a baseline level of second analyte level 314b (e.g., ketone, lactate, lactic acid, alcohol) by calculating an average (e.g., sum of sensor data levels divided by the total number of entries), a median (e.g., middle of upper and lower halves of sensor data sample), a linear regression (e.g., trend line), a non-linear regression, or any other suitable calculation to determine a baseline. The period of data used in this calculation may be defined as a period when the data do not exceed a predefined level of variability. For instance, the period may be defined simply as a period when the ketone values never exceed a threshold. After a baseline level is established, the system may subtract this baseline level from the ketone values so that the display shows this level as zero. Alternatively, the graphic representation of the ketone value may indicate zero ketones when the measured ketones is at this level.

[0160] In some aspects, software application 300 can be configured to perform analytics of sensor data 312 to determine predictive model 324. For example, predictive model 324 can determine a trend line or future statistical value of sensor data 312 (e.g., first analyte level 314a, second analyte level 314b, etc.). In some aspects, predictive model 324 can be based on a population model. For example, predictive model 324 can be based on population model 326 and one or more parameters that modulate predictive model 324 into a range of known variations from population model 326. In some aspects, predictive model 324 can be based on a predictive algorithm. For example, predictive model can be based on predictive algorithm 328 that can include, but is not limited to, regression, model-based parameter adaptation, supervised machine learning, unsupervised machine learning, semi-supervised machine learning, reinforced learning, clustering, decision trees, anomaly detection, neural networks, classification models, or a combination thereof. In some aspects, predictive model 324 can increase accuracy and precision of estimates regarding a patient's future analyte levels, for example, glucose and/or ketone levels. In some aspects, predictive model 324 can estimate a likelihood of a future condition (e.g., a high ketone condition) and present the likelihood to the patient (e.g., a notification).

[0161] In some aspects, predictive model 324 can be employed using the data inputs and result outputs described herein (e.g., sensor data 312) and estimate the likelihood of a high ketone event and present the estimation to the patient. For example, software application 300 can present the

estimation of predictive model on demand (e.g., as part of the ketone measurement screen) or as a notification (e.g., notification 352) when a condition is detected (e.g., 50% change of a high ketone event).

[0162] In some aspects, predictive model 324 can be developed based on standard modeling techniques using data from a population of patients (e.g., population model 326), where the data inputs and result outputs described herein (e.g., sensor data 312) are retrieved. For example, predictive model 324 can be adaptive (e.g., customized) to a particular patient when sufficient input and/or output data from that particular patient are retrieved. In some aspects, predictive model 324 can be based on a population of patients (e.g., population model 326) that is used in the beginning of a patient's sensor wear. For example, over time, if there are certain parameters that modulate predictive model 324 into a range of known variations from population model 326, these parameters can be estimated and updated over time. In some aspects, predictive model 324 can utilize population model 326 and one or more updated parameters to better estimate a patient's analyte levels. For example, with an updated parameter, predictive model 324 can better estimate the patient's near-future ketone levels. In some aspects, predictive model 324 can use standard regression techniques, model-based parameter adaptation, supervised machine learning, unsupervised machine learning, semi-supervised machine learning, reinforced learning, clustering, decision trees, or anomaly detection, for example, with predictive algorithm 328. In some aspects, predictive model 324 can use classification based approaches, for example, with predictive algorithm 328. For example, predictive model 324 can use one or more classification models to present a small quantized set of value ranges.

[0163] Settings system 330 can be configured to provide one or more predetermined settings 332 of software application 300, for example, to conditional logic system 310. Settings system 330 can be further configured to adjust one or more predetermined settings 332 of software application 300. Settings system 330 can be operatively coupled to conditional logic system 310, notification system 350, and/or dose control system 370. As shown in FIG. 3, settings system 330 can include predetermined settings 332, thresholds 334, adjustment settings 340, input/output (I/O) subsystem 342, and/or user interface (UI) subsystem 344. In some aspects, settings system 330 can include enabling an interface (e.g., UI subsystem 344) with a remote bolus calculator or dose guidance system (e.g., dose guidance 374 of dose control system 370), including an AID system (e.g., IDS 190).

[0164] Predetermined settings 332 can be configured to provide a comparison value (e.g., threshold) to sensor data 312 for software application 300 to detect conditional logic states of a patient (e.g., conditional logic states 10, 20, 30, 40, 50, 60, 70). As shown in FIG. 3, predetermined settings 332 can be coupled to conditional logic system 310 to determine if sensor data 312 (e.g., first and second analyte levels 314a, 314b) are below or above predetermined settings 332. In some aspects, as shown in FIG. 3, predetermined settings 332 can include one or more thresholds, for example, thresholds 334 (e.g., first analyte thresholds 336, second analyte thresholds 338).

[0165] In some aspects, software application 300 can be configured to operate on conditional logic (e.g., conditional logic system 310) based on predetermined settings 332. In some aspects, software application 300 can be configured to adjust predetermined settings 332. For example, based on one or more parameters of a patient (e.g., known illness, SGLT-2 inhibitor medication, insulin delivery rate, etc.), software application 300 can adjust (e.g., increase or decrease) one or more thresholds 334. In some aspects, predetermined settings 332 can include a plurality of thresholds. For example, predetermined settings 332 can include thresholds 334.

[0166] In some aspects, predetermined settings 332 can include a first threshold value of the first analyte (e.g., first analyte threshold 336) and a second threshold value of the second analyte (e.g., second analyte threshold 338). For example, first analyte threshold 336 (e.g., glucose) can be a high glucose threshold (e.g., about 180 mg/dL), and second analyte threshold 338 (e.g., ketones, lactate, lactic acid, alcohol) can be a high ketone threshold (e.g., about 3.0 mmol/L). In some aspects, predetermined settings 332 can include first and second threshold values of the first analyte (e.g., first analyte thresholds 336) and third and fourth threshold values of the second analyte (e.g., second analyte thresholds 338). For example, first analyte thresholds 336 (e.g., glucose) can be a low glucose threshold (e.g., about 70 mg/dL) and a high glucose threshold (e.g., about 180 mg/dL), and second analyte threshold 338 (e.g., ketones, lactate, lactic acid, alcohol) can be a moderate ketone threshold (e.g., about 1.0 mmol/L) and a high ketone threshold (e.g., about 3.0 mmol/L).

[0167] In some aspects, software application 300 can provide default predetermined settings 332 for condition thresholds (e.g., thresholds 334, such as glucose and ketone thresholds), warning text (e.g., warning 354), recommendation action or treatment text (e.g., recommendation 356), and/or prompt text (e.g., prompt 358). In some aspects, software application 300 can edit these settings or provide an opportunity to edit these settings (e.g., adjustment settings 340). For example,

software application 300 can update predetermined settings 332 and require a patient or HCP to confirm the edited settings, or software application 300 can make these settings available for adjustment via a setup menu (e.g., adjustment settings 340).

[0168] In some aspects, predetermined settings 332 can include default thresholds (e.g., thresholds 334). For example, default thresholds (e.g., first and second analyte thresholds 336, 338) can include a low glucose threshold (e.g., about 70 mg/dL), a moderate glucose threshold (e.g., about 110 mg/dL), a high glucose threshold (e.g., about 180 mg/dL), a low ketone threshold (e.g., about 0.5 mmol/L), a moderate ketone threshold (e.g., about 1.0 mmol/L), and/or high ketone threshold (e.g., about 3.0 mmol/L). In some aspects, software application 300 (e.g., via predetermined settings 332) can be extended to any number of thresholds (e.g., thresholds 334) with distinct text associated with each conditional logic state defined by these thresholds.

[0169] Thresholds 334 can be configured to define a value or range of sensor data 312 to detect conditional logic states of a patient (e.g., conditional logic states 10, 20, 30, 40, 50, 60, 70). Thresholds 334 can be further configured to provide a comparison value or range to determine if sensor data 312 is below, above, or within thresholds 334. As shown in FIG. 3, thresholds 334 can include first analyte threshold(s) 336 (e.g., one or more glucose thresholds) and second analyte threshold(s) 338 (e.g., one or more ketone thresholds). In some aspects, thresholds 334 can be default thresholds, thereby defining default corresponding conditional logic states. In some aspects, software application 300 can utilize default or editable thresholds 334 (e.g., glucose and ketone thresholds) to provide notifications (e.g., warning, recommendation, guidance, prompts) associated with each conditional logic state defined by the thresholds.

[0170] In some aspects, first analyte threshold(s) 336 can include one or more first analyte thresholds (e.g., one or more glucose thresholds). For example, first analyte thresholds 336 can include a low glucose threshold (e.g., about 70 mg/dL), a moderate glucose threshold (e.g., about 110 mg/dL), and/or a high glucose threshold (e.g., about 180 mg/dL). In some aspects, second analyte threshold(s) 338 can include one or more second analyte thresholds (e.g., one or more ketone thresholds). For example, second analyte thresholds 338 can include a low ketone threshold (e.g., about 0.5 mmol/L), a moderate ketone threshold (e.g., about 1.0 mmol/L), and/or a high ketone threshold (e.g., about 3.0 mmol/L).

[0171] Adjustment settings 340 can be configured to adjust one or more parameters of predetermined settings 332. Adjustment settings 340 can be further configured to provide

additional information or data to software application 300 to detect conditional logic states of a patient. As shown in FIG. 3, adjustment settings 340 can be coupled to predetermined settings 332 and conditional logic system 310 to adjust one or more thresholds and thereby adjust detection of conditional logic states.

[0172] In some aspects, software application 300 can be configured to adjust the conditional logic based on a ROC of the first analyte level (e.g., glucose ROC) and/or a ROC of the second analyte level (e.g., ketone ROC). For example, adjustment settings 340 can include one or more ROC thresholds (e.g., one or more glucose ROC thresholds, one or more ketone ROC thresholds) that can be compared to first analyte ROC 316a and/or second analyte ROC 316b of sensor data 312 to detect a conditional logic state. In some aspects, software application 300 can be configured to adjust the conditional logic based on insulin sensitivity, carbohydrate ratio, patient disease state, patient medication regimen, and/or pairing with a remote dose system. For example, adjustment settings 340 can detect pairing with a remote dose system (e.g., IDS 190) and adjust the conditional logic (e.g., predetermined settings 332) based on insulin dose amounts. In some aspects, software application 300 can adjust (e.g., optimize) the conditional logic based on one or more ranges of various parameters (e.g., glucose ROC, ketone ROC, insulin sensitivity, carbohydrate ratio, patient disease state, patient medication regimen, remote dose system, etc.). For example, adjustment settings 340 can be based on one or more equations associating the various parameters with, for example, insulin dose amounts to define or adjust predetermined settings 332 (e.g., thresholds 334). In some aspects, adjustment settings 340 can be based on one or more equations dependent upon an analyte measurement (e.g., ketone level). For example, as shown in FIG. 12, the equations can include basal insulin (Basal) = $f(\text{Ketones})$ [units per day], insulin sensitivity (IS) = $f(\text{Ketones})$ [mg/dL per unit], and/or carbohydrate ratio (CR) = $f(\text{Ketones})$ [grams per unit]. In some aspects, adjustment settings 340 can be based on one or more conditional equations, for example, an IF-THEN conditional equation. For example, as shown in FIG. 12, the conditional equation can include:

If ketones < 1.0 mmol/L,
 Then IS = 4 mg/dL/Unit (or in common notation, 1:4)
 If ketones $\geq$ 1.0 AND < 3.0 mmol/L,
 Then IS = $4 + \{(\text{ketone} - 1)/2\} * 4 \text{ mmol/L}$
 Otherwise ketones = 8 mmol/L.

[0173] In some aspects, adjustment settings 340 can include insulin dose amounts (e.g., via IDS 190). For example, as shown in FIG. 11, the insulin dose amounts can be associated with different glucose and ketone ranges as in exemplary dose guidance system 1100, and the dose settings can be defined by insulin type, insulin units, total daily dose (TDD), and/or percent TDD. In some aspects, adjustment settings 340 can define insulin dose parameters as an equation of an analyte measurement (e.g., ketone level). For example, as shown in FIG. 12, the insulin dose parameters, including but not limited to basal insulin (Basal), insulin sensitivity (IS), and carbohydrate ratio (CR), can each be defined as a function of ketone value, $f(\text{Ketones})$, as in exemplary glycemic response model 1200, for example, ketone level, ketone ROC, ketone-based metric, etc.

[0174] In some aspects, adjustment settings 340 can define insulin dose parameters as an equation with ketone value (e.g., ketone level, ketone ROC, ketone-based metric, etc.) as an input and insulin dose or percent TDD as an output, and the equation parameters can be part of adjustment settings 340. For example, the percent TDD can be a function of ketone value, or the amount of insulin calculated can be subtracted up to a function of ketone value. In some aspects, adjustment settings 340, instead of a function of ketone value, can use a different function based on ranges of ketone values, for example, using two or more ranges of ketone values as an input to a function that modifies the insulin dose. In some aspects, adjustment settings 340 can include insulin sensitivity (IS) to determine a recommended insulin dose (e.g., dose recommendation 378 of dose control system 370), for example, to reduce high glucose levels.

[0175] In some aspects, adjustment settings 340 can include carbohydrate amounts or carbohydrate ratios (CRs) to define an amount of insulin to cover a specific number of carbohydrates, or conversely, to define an amount of carbohydrates to cover a specific amount of insulin. For example, as shown in FIG. 11, for the case of low glucose levels and high ketone levels as in exemplary dose guidance system 1100, adjustment settings 340 can define carbohydrate ratio (CR) as 1:5 (U:g) and recommend taking 10U of insulin and carbohydrate ingestion of $5/\text{CR} + 15$ g (15 g to cover low glucose).

[0176] In some aspects, adjustment settings 340 can include insulin sensitivity (IS) and/or carbohydrate ratio (CR) defined as a range of parameters to determine a recommended insulin dose, for example, where each element of the range of parameters is associated with a range of glucose and/or a range of ketones. For example, software application 300 can accommodate for when a patient's insulin sensitivity (IS) is lower in the previous day or for when a patient's insulin

sensitivity (IS) indirectly causes high ketone readings. In some aspects, adjustment settings 340 can include insulin sensitivity (IS) and/or carbohydrate ratio (CR) defined as functions where glucose and/or ketones are inputs and insulin sensitivity (IS) and/or carbohydrate ratios (CR) are the outputs. For example, adjustment settings 340 can include adjustable equation parameters of the defined functions.

[0177] In some aspects, software application 300 can include a setting to indicate a patient's disease state (e.g., known illness) and/or medication regimen. For example, adjustment settings 340 can enable features if the patient is a type-1 diabetes patient using SGLT-2 inhibitors and thereby adjust detection of conditional logic states based on this patient information. In some aspects, software application 300 can include a setting to indicate whether a patient is using an insulin pump, insulin pen, and/or AID system (e.g., IDS 190), or whether the patient is on a carb-restricted diet. For example, adjustment settings 340 can enable features to alter text associated with the condition logic (e.g., notification 352) and/or alter the condition logic itself (e.g., condition detection 320) based on this patient information.

[0178] In some aspects, for a patient on a carb-restricted diet, adjustment settings 340 can automatically or manually (e.g., via a clinician) adjust one or more threshold settings (e.g., thresholds 334) to accommodate the carb-restricted diet. For example, software application 300 can automatically increase a moderate ketone threshold (e.g., 1.0 mmol/L to 1.5 mmol/L) if the carb-restricted diet option is selected or a clinician can manually increase the moderate ketone threshold in software application 300. In some aspects, software application 300 can conduct periodic data analyses to assess whether a patient can maintain moderately high ketones (e.g., between 1.0-3.0 mmol/L) without causing high ketones (e.g., above 3.0 mmol/L). For example, adjustment settings 340 can periodically monitor the patient's ketone levels and automatically set a moderate ketone threshold (e.g., about 1.0 mmol/L) or recommend in a report (e.g., reporting 364) to a clinician or HCP how to adjust the moderate ketone threshold.

[0179] In some aspects, software application 300 can provide instructions to a patient to discontinue use of a medication regimen (e.g., SGLT-2 inhibitors, etc.) until instructed otherwise. For example, for a patient (e.g., type-1 diabetes patient) using SGLT-2 inhibitors, notifications (e.g., recommendations) for moderate ketone levels or high ketone levels can include instructions to discontinue use of SGLT-2 inhibitors until instructed by the patient's HCP to start medication again.

[0180] I/O subsystem 342 can be configured to receive and send data between conditional logic system 310, settings system 330, notification system 350, and/or dose control system 370. As shown in FIG. 3, I/O subsystem 342 can be coupled to predetermined settings 332, adjustment settings 340, and UI subsystem 344. In some aspects, I/O subsystem 342 can send and receive data between software application 300 and one or more devices of analyte monitoring system 100 (e.g., analyte sensor 122, OBU 120, display device 130, remote server 180, etc.). In some aspects, I/O subsystem 342 can send and receive data between all components and subcomponents of software application 300 (e.g., conditional logic system 310, settings system 330, notification system 350, dose control system 370, etc.). In some aspects, a patient can transfer data or adjust settings in software application 300 via I/O subsystem 342, for example, with UI subsystem 344.

[0181] In some aspects, I/O subsystem 342 can send predetermined settings 332 to conditional logic system 310, which can compare sensor data 312 to predetermined settings 332 to detect conditional logic states (e.g., via condition detection 320). In some aspects, I/O subsystem 342 can receive a detected condition (e.g., conditional logic state 10) from conditional logic system 310, retrieve one or more notifications 352 from notification system 350 based on the detected condition, and send the corresponding notifications 352 to an external device (e.g., display device 130, remote server 180, etc.). In some aspects, I/O subsystem 342 can receive additional information (e.g., contextual data 362) from a patient based on prompts from notification system 350 (e.g., prompts 358) and send the additional information to conditional logic system 310 to adjust the conditional logic and/or reporting to a HCP (e.g., reporting 364). In some aspects, I/O subsystem 342 can receive dose guidance (e.g., dose guidance 374) or IDS control instructions (e.g., IDS control 372) from dose control system 370 and send the information to an external insulin delivery system (e.g., IDS 190, smart insulin pen, etc.).

[0182] UI subsystem 344 can be configured to provide one or more user interfaces that allow a user to interact with software application 300. UI subsystem 344 can be further configured to send data to conditional logic system 310, settings system 330, notification system 350, and/or dose control system 370. As shown in FIG. 3, UI subsystem 344 can be coupled to predetermined settings 332 to confirm or modify predetermined settings 332 (e.g., thresholds 334). In some aspects, UI subsystem 344 can provide a user interface for entering, confirming, or modifying predetermined settings 332 (e.g., thresholds 334), for example, based on different treatment plans or medication regimen. In some aspects, UI subsystem 344 can receive user input via one or more

input devices, for example, a keyboard, mouse, touch-screen, gesture, or any other suitable input device (e.g., display device 130). In some aspects, UI subsystem 344 can display and manipulate a model of one or more analyte measurements (e.g., display 140 with menu input 148 and graph input 152). In some aspects, UI subsystem 344 can enter or modify notifications (e.g., warnings 354, recommendations 356, prompts 358) of notification system 350.

[0183] Notification system 350 can be configured to provide custom notifications (e.g., warnings, recommendations, guidance, prompts, etc.) based on a detected condition. Notification system 350 can be further configured to provide custom notifications to the patient at appropriate times. Notification system 350 can be operatively coupled to conditional logic system 310, settings system 330, and/or dose control system 370. As shown in FIG. 3, notification system 350 can include notification 352, second notification 360, contextual data 362, and/or reporting 364.

[0184] Notification 352 can be configured to provide one or more notifications (e.g., text, alerts, guidance, prompts, etc.) based on a detected conditional logic state (e.g., conditional logic states 10, 20, 30, 40, 50, 60, 70). As shown in FIG. 3, notification 352 can include warning 354, recommendation 356, prompt 358, or a combination thereof. In some aspects, notification 352 can include one or more notifications (e.g., warning 354, recommendation 356, prompt 358) based on a detected condition (e.g., condition detection 320) to one or more external devices (e.g., display device 130, remote server 180, etc.). For example, as shown in FIGS. 4B, 5B, 6B, 7B, 8B, 9B, and 10B, corresponding display notification(s) 400B–1000B for different conditional logic states 10, 20, 30, 40, 50, 60, 70 of software application 300 can be provided, respectively, for example, on display 140.

[0185] In some aspects, software application 300 can detect (e.g., in real-time) when a conditional logic state (e.g., glucose-ketone condition) occurs and the conditional logic states are determined by predetermined thresholds (e.g., predetermined settings 332). For example, as shown in FIGS. 4A–10B, software application 300 can utilize state diagrams 400A–1000A and corresponding display notification(s) 400B–1000B for different conditional logic states 10, 20, 30, 40, 50, 60, 70.

[0186] In some aspects, when a condition is first detected, software application 300 will send a notification to the patient (e.g., notification 352), for example, to display 140 of display device 130. In some aspects, software application 300 can include an alarm function. For example, the alarm function can include a button or other input element for the patient to acknowledge and

silence the alarm, for example, alarm display 156 of display 140. In some aspects, if notification 352 (e.g., alarm, alert) is ignored, notification 352 will sound off for a short time period (e.g., about 15 seconds) and then reoccur periodically (e.g., every 15 minutes) until notification 352 is acknowledged, for example, via second notification 360. In some aspects, notification 352 (e.g., alarm, alert) can be provided to others (e.g., clinician, HCP, patient family members, etc.), for example, using a caregiver software application. For example, software application 300 can be downloaded and used by one or more caregivers, separate from a patient's software application 300, and receive one or more notifications 352 (e.g., ketone warnings).

[0187] In some aspects, software application 300 can be designed to modify the behavior of alarms presented (e.g., notifications 352) since analyte condition states (e.g., glucose and ketone condition states) may transition at different times. For example, software application 300 can present a low glucose alarm at one point in time and at a later time (e.g., a few minutes) present a moderate ketone and low glucose alarm, such that the low glucose alarm behavior after an initial notification can be altered or suppressed in favor of the moderate ketone and low glucose alarm post-notification behavior.

[0188] Warning 354 can be configured to provide custom warnings (e.g., text) based on a detected condition. As shown in FIG. 3, warning 354 can be based on a detected condition (e.g., condition detection 320) and provided by software application 300. In some aspects, warning 354 can include one or more warnings based on a detected condition (e.g., condition detection 320) to one or more external devices (e.g., display device 130, remote server 180, etc.). For example, as shown in FIGS. 4B, 5B, 6B, 7B, 8B, 9B, and 10B, corresponding warnings 406b, 506b, 606b, 706b, 808b, 908b, 1008b for different conditional logic states 10, 20, 30, 40, 50, 60, 70 of software application 300 can be provided, respectively, for example, on display 140.

[0189] In some aspects, warning 354 can continue to display whenever a patient accesses a current analyte reading and/or analyte display in software application 300, for example, a current ketone reading on display 140. In some aspects, when software application 300 detects a condition (e.g., high ketone levels) and provides warning 354 to a patient, software application 300 can include a button or other input element to display a recommendation (e.g., recommendation 356) and/or other text associated with the detected condition (e.g., prompt 358).

[0190] In some aspects, when software application 300 detects a condition (e.g., high ketone levels) and provides warning 354 to a patient, software application 300 can automatically display

a recommendation (e.g., recommendation 356) and/or other text associated with the detected condition (e.g., prompt 358), for example, on display 140 showing current ketone reading (e.g., numerical display 146) and/or ketone display (e.g., graphical display 142). In some aspects, warning 354 can provide a warning or text to the patient based on the detected condition and can include a recommendation (e.g., recommendation 356). For example, warning 354 can include recommended insulin and/or carbohydrate amounts (e.g., ingest 15 grams of carbs).

[0191] Recommendation 356 can be configured to provide custom recommendations (e.g., text) for the patient to act based on a detected condition. As shown in FIG. 3, recommendation 356 can be based on a detected condition (e.g., condition detection 320) and provided by software application 300. In some aspects, recommendation 356 can include one or more recommendations based on a detected condition (e.g., condition detection 320) to one or more external devices (e.g., display device 130, remote server 180, etc.). For example, as shown in FIGS. 4B, 8B, 9B, and 10B, corresponding recommendations 408b, 810b, 910b, 1010b for different conditional logic states 10, 50, 60, 70 of software application 300 can be provided, respectively, for example, on display 140.

[0192] In some aspects, recommendation 356 can include recommended insulin and/or carbohydrate amounts. For example, as shown in FIG. 9B, for detected moderate ketone levels and moderate glucose levels (e.g., conditional logic state 60), recommendation 910b can include recommended insulin and carbohydrate amounts (e.g., “if you have not injected insulin with the last 3 hours, ingest 15 grams of carbs and inject sufficient insulin to cover these carbs”), for example, on display 140 subsequent to warning 908b.

[0193] Prompt 358 can be configured to provide custom prompts (e.g., text) based on a detected condition. Prompt 358 can be further configured to retrieve additional information (e.g., contextual data 362) regarding the detected condition. As shown in FIG. 3, prompt 358 can be based on a detected condition (e.g., condition detection 320) and provided by software application 300. In some aspects, prompt 358 can include one or more prompts based on a detected condition (e.g., condition detection 320) to one or more external devices (e.g., display device 130, remote server 180, etc.). For example, as shown in FIGS. 5B, 6B, 7B, 8B, 9B, and 10B, corresponding prompts 508b, 608b, 610b, 708b, 812b, 912b, 1012b for different conditional logic states 20, 30, 40, 50, 60, 70 of software application 300 can be provided, respectively, for example, on display 140.

[0194] In some aspects, software application 300 can be configured to provide prompt 358 to the patient to retrieve additional information regarding the condition. For example, software

application 300 can prompt the patient for additional information (e.g., contextual data 362) relevant to the detected condition at appropriate times, for example, immediately after the condition is detected. In some aspects, software application 300 can capture additional information (e.g., contextual data 362) about the patient's condition at the moment when the patient will remember it, for example, to assist a clinician or HCP determine an underlying cause of the condition. In some aspects, the additional information can include contextual data of the condition (e.g., contextual data 362). In some aspects, software application 300 can be configured to adjust a threshold value (e.g., thresholds 334) of the first analyte (e.g., glucose) and/or the second analyte (e.g., ketones, lactate, lactic acid, alcohol) based on contextual data 362.

[0195] In some aspects, contextual data 362 can include a frequency of the condition, for example, the number of times the condition occurs in an hour, six hours, twelve hours, a day, a week, a month, etc. In some aspects, contextual data 362 can include a discomfort level of the patient, for example, based on a numerical scale (e.g., 0 to 3 in increasing discomfort). For example, as shown in FIG. 7B, prompt 708b can include a list of discomfort levels for the patient to select (e.g., “0 – No discomfort; 1 – Little discomfort; 2 – Admitted to emergency medical services, modest symptoms; 3 – Admitted to emergency medical services, severe symptoms”).

[0196] In some aspects, if prompt 358 (e.g., text, list) has not been answered by the patient, prompt 358 will sound off for a short time period (e.g., about 15 seconds) and then reoccur periodically (e.g., every hour) until prompt 358 is acknowledged and answered, for example, via second notification 360. In some aspects, software application 300 can log or store the patient's answers or selections to prompt 358 (e.g., contextual data 362). For example, once this information is entered and logged (e.g., contextual data 362), prompt 358 can be discontinued until the next time the condition is detected.

[0197] In some aspects, prompt 358 can be used to determine if the patient is ill and details about the illness. For example, prompt 358 can include a series of questions for the patient to answer (e.g., similar to a clinician or HCP) to isolate and determine the illness (e.g., high ketone episode, DKA, euDKA, etc.). In some aspects, software application 300 can log or store the patient's answers or selections to one or more prompts 358. For example, once this information is entered and logged, the information can be provided to a clinician or HCP (e.g., reporting 364) to help determine one or more underlying causes of the illness, for example, a high ketone episode.

[0198] Second notification 360 can be configured to provide a follow-up notification (e.g., alert, alarm, warning, recommendation, prompt) if notification 352 is ignored or not acknowledged by the patient within a specified time period. As shown in FIG. 3, second notification 360 can be based on a time period or a patient's response to notification 352 and provided by software application 300. In some aspects, software application 300 can provide second notification 360 to the patient (e.g., via display 140) if the detected condition remains unchanged after a predetermined time period (e.g., about 15 minutes). In some aspects, if notification 352 (e.g., alert, alarm, warning, recommendation, prompt) is ignored, notification 352 will sound off for a short time period (e.g., about 15 seconds) and then second notification 360 will reoccur periodically (e.g., every 15 minutes) until notification 352 is acknowledged.

[0199] In some aspects, second notification 360 can be utilized when software application 300 is paired with an insulin delivery pump or insulin pen (e.g., IDS 190). For example, if software application 300 provides a recommended dose (e.g., insulin dose), but after a specified period of time (e.g., about 15 minutes) the recommended dose has not been delivered within a specified delivery period (e.g., within the past 3 hours and 15 minutes) and the detected condition remains unchanged, then software application 300 can generate second notification 360 to resend notification 352 and indicate that this is a repeated notification and continue periodically sending second notification 360 as long as the detected condition remains unchanged.

[0200] Contextual data 362 can be configured to provide contextual information (e.g., patient discomfort, contributing factors, medications taken, etc.) related to a detected condition to assist a clinician or HCP determine an underlying cause of the condition. As shown in FIG. 3, contextual data 362 can be received from the patient in response to one or more prompts 358. In some aspects, software application 300 can prompt the patient for contextual data 362 relevant to the detected condition at appropriate times, for example, immediately after the condition is detected when the patient will remember it.

[0201] In some aspects, contextual data 362 can include a frequency of the condition, for example, the number of times the condition occurs in an hour, six hours, twelve hours, a day, a week, a month, etc. In some aspects, contextual data 362 can include a discomfort level of the patient, for example, based on a numerical scale (e.g., 0 to 3 in increasing discomfort). For example, as shown in FIG. 7B, contextual data 362 can include a patient's selection from a list of discomfort levels (e.g., "2 – Admitted to emergency medical services, modest symptoms"). In

some aspects, software application 300 can log or store contextual data 362. For example, once contextual data 362 is entered and logged, prompt 358 can be discontinued until the next time the condition occurs. In some aspects, contextual data 362 can be reported to a clinician or HCP, for example, via reporting 364.

[0202] Reporting 364 can be configured to report information to one or more external devices (e.g., display device 130, remote server 180, etc.). Reporting 364 can be further configured to generate reports (e.g., graphs, trends, time traces, etc.) of a patient's information, including analyte measurements, detected condition(s), and/or inputs from the patient (e.g., contextual data 362). As shown in FIG. 3, reporting 364 can be sent via software application 300 to a patient (e.g., display device 130) or a clinician or HCP (e.g., remote server 180).

[0203] In some aspects, reporting 364 can include daily time traces of one or more analytes (e.g., glucose, ketones, lactate, lactate acid, alcohol), for example, similar to current glucose daily reports. In some aspects, reporting 364 can collocate two or more analytes (e.g., any combination of glucose, ketones, lactate, lactate acid, alcohol) on the same report. In some aspects, reporting 364 can include a glucose time-trace plot annotated with ketone-centric information. For example, colored bands (e.g., green = low ketone range, yellow = moderate ketone range, red = high ketone range) or other indicators of ketone levels or ketone ranges can be annotated on the glucose time-trace plot.

[0204] In some aspects, information gathered from prompts 358 of software application 300 (e.g., contextual data 362) can be used to annotate daily time traces of one or more analytes (e.g., ketones, lactate, lactic acid, alcohol). For example, a symbol or indicator representing a cause of a high ketone episode (or the text of the cause itself) can be located vertically coincident with the time the cause was logged or with the time ketone levels started increasing. In some aspects, an icon or symbol associated with a cause of a condition detected (e.g., insulin pump failure) can be placed at the start of the associated ketone level increase on the report. In some aspects, information from patient (e.g., contextual data 362) can be annotated on the trace or report, for example, discomfort level information from the patient can be included on the trace at the start, middle, and/or end of the associated event (e.g., high ketone episode).

[0205] In some aspects, reporting 364 can include other metrics configured to provide insight to a clinician or HCP regarding the patient's condition. For example, reporting 364 can include a frequency (e.g., occurrences per year) of high ketone events, moderate ketone events, high ketone

events occurring with normal target range glucose levels, all glucose and ketone ranges possible, high ketone causes, ketone baseline level, or a combination thereof. In some aspects, reporting 364 can include a frequency of an analyte condition (e.g., high ketone episode) with information from the patient (e.g., contextual data 362). For example, the frequency of causes and the distribution of discomfort levels for high ketone events over the past year can be reported. In some aspects, reporting 364 can identify and display an indication that a medication regimen (e.g., using SGLT-2 inhibitors) or a carb-restricted diet are not advised for a patient based on reported metrics, for example, if the patient has had two or more occurrences of high ketone events in the past year.

[0206] In some aspects, reporting 364 can include a relationship (e.g., correlation) between moderate ketone levels and high ketone levels. For example, how often high ketone events occur after a moderate ketone event can be reported. In some aspects, reporting 364 can include a modal day plot (e.g., 24 hr graph) of one or more analytes (e.g., ketones, lactate, lactic acid, alcohol), for example, to identify a time-of-day prevalence for high ketones. In some aspects, reporting 364 can include a modal week plot (e.g., 7 day graph) of one or more analytes (e.g., ketones, lactate, lactic acid, alcohol), for example, to identify days of the week for which a patient might be at a higher risk (e.g., high ketone events) and assist in determining one or more factors causing the high ketone events.

[0207] In some aspects, reporting 364 can include a modal day plot (e.g., 24 hr graph) of continuous ketone levels. For example, the modal day plot can include individual ketone traces or ketone percentile traces (e.g., 5th percentile, 25th percentile, 50th percentile, 75th percentile, 95th percentile, etc.) calculated for each hour of the day. In some aspects, reporting 364 can include overlay plots (e.g., different plots on top of each other) time aligned to key events of an analyte trace (e.g., ketone trace). For example, overlay plots can be time aligned to when ketone levels start increasing or when ketone levels cross a certain threshold (e.g., high ketone threshold).

[0208] In some aspects, software application 300 can associate a patient's discomfort levels (e.g., contextual data 362) to determine an efficacy of a treatment plan. For example, a metric (e.g., dose of SGLT-2 inhibitor, daily exercise, weight loss, etc.) can be calculated and presented via reporting 364 to show that if the recommended treatment plan was followed, then high ketone episodes were mitigated or resulted in decreased discomfort levels. In some aspects, reporting 364 can present a frequency of high ketone events and corresponding distribution of discomfort levels. For example, reporting 364 can present a report showing the frequency of high ketone events when

treatment was followed versus when treatment was not followed or delayed, and the distribution of corresponding discomfort levels when high ketone events occurred when treatment was followed versus when treatment was not followed or delayed.

[0209] In some aspects, information from reporting 364 (e.g., efficacy of treatment plan) can be utilized by software application 300 to determine one or more thresholds 334 (e.g., low ketone threshold). For example, an analysis from reporting 364 can determine that, for a particular patient, ketone levels up to 1.4 mmol/L do not transition above a high ketone threshold (e.g., 3.0 mmol/L) while ketone levels above 1.4 mmol/L do transition into high ketone levels (e.g., above 3.0 mmol/L), indicating that a low ketone threshold can be set to about 1.4 mmol/L. In some aspects, software application 300 can periodically perform analysis from reporting 364 and automatically adjust one or more thresholds 334 (e.g., low ketone threshold) based on data from reporting 364. In some aspects, software application 300 can periodically perform analysis from reporting 364 and report the data to a clinician or HCP for manual adjustment of one or more thresholds 334 (e.g., low ketone threshold).

[0210] In some aspects, reporting 364 can include time traces of individual analyte events (e.g., moderate and high ketone events) annotated or aligned with other information to illustrate an efficacy of a treatment plan. For example, time traces of individual moderate and ketone events can be annotated with meal logs, insulin delivery logs or records, glucose traces, and/or other possible data to show the efficacy of the treatment plan to mitigate high ketone events.

[0211] Dose control system 370 can be configured to control and/or operate an insulin delivery system (e.g., insulin pump, insulin pen, AID system, IDS 190, etc.). Dose control system 370 can be further configured to provide dose guidance to a patient. Dose control system 370 can be further configured to utilize a glycemic model (e.g., glycemic response model 376) to provide a recommended dose based on one or more glycemic parameters. Dose control system 370 can be operatively coupled to conditional logic system 310, settings system 330, and/or notification system 350. As shown in FIG. 3, dose control system 370 can include IDS control 372, dose guidance 374, glycemic response model 376, additional data 382 (e.g., an additional sensor), and/or dose titration 384.

[0212] In some aspects, dose control system 370 can control insulin delivery based on first analyte level 314a (e.g., glucose) and second analyte level 314b (e.g., ketones, lactate, lactic acid, alcohol). For example, dose control system 370 can control insulin delivery based on glucose

levels and ketone levels. In some aspects, dose control system 370 can calculate insulin dose based on glucose levels and modify the insulin dose based on ketone levels. In some aspects, dose control system 370 can adjust insulin delivery parameters based on glucose levels and ketone levels, for example, insulin sensitivity factor (ISF), carbohydrate ratio (CR), etc.

[0213] IDS control 372 can be configured to control and/or operate an insulin delivery system (e.g., insulin pump, insulin pen, AID system, IDS 190, etc.). IDS control 372 can be further configured to send and receive data to and from the insulin delivery system (e.g., IDS 190). As shown in FIG. 3, IDS control 372 can be coupled to glycemic response model 376 and provide control instructions to the insulin delivery system (e.g., IDS 190). In some aspects, if software application 300 has been configured for an insulin pump patient (e.g., paired with IDS 190), recommendation 356 can include instructions related to insulin delivery, for example, checking proper operation of the pump (e.g., tubing pressure) to ensure insulin and the correct amount of insulin are being delivered.

[0214] In some aspects, for AID system applications (e.g., IDS 190), the AID system (e.g., IDS 190) may suspend insulin delivery, but recommendation 356 can include instructions to manually override the AID system to restart insulin delivery, for example, if ketone levels are high and glucose levels are low or moderate (e.g., mitigate risk of euDKA). In some aspects, for AID system applications (e.g., IDS 190), software application 300 can connect (e.g., wirelessly or electronically) with the AID system (e.g., IDS 190) and automatically override the AID system to restart insulin delivery if the AID system suspends insulin delivery, for example, if ketone levels are high but glucose levels are low or moderate (e.g., mitigate risk of euDKA). For example, IDS control 372 can send control instructions to restart insulin delivery and recommendation 356 can include instructions that the patient consume carbohydrates as part of the treatment.

[0215] Dose guidance 374 can be configured to provide dose guidance to a patient (e.g., insulin dose, carb dose, etc.). As shown in FIG. 3, dose guidance 374 can be coupled to notification system 350 and provide dose guidance to the patient (e.g., recommendation 356) and/or be coupled to IDS control 372 and provide dose guidance to an insulin delivery system (e.g., IDS 190). In some aspects, dose guidance 374 can be operatively coupled to software application 300, for example, predictive model 324. In some aspects, dose guidance 374 can include a bolus calculator.

[0216] In some aspects, for patient's that use a bolus calculator or a dose guidance system, dose guidance 374 can provide specific recommendations for dosing and carb ingestion. For example,

dose guidance 374 can instruct software application 300 to provide one or more recommendations 356 instructing the patient to inject a certain amount of insulin (e.g., inject 5U of insulin, 1U = 34.7 μ g of insulin) and consume a certain amount of carbohydrates (e.g., consume 15 grams of carbs) as part of the treatment.

[0217] In some aspects, dose guidance 374 can include one or more analyte tables (e.g., array, matrix, etc.) for a dose guidance system. For example, as shown in FIG. 11, exemplary dose guidance system 1100 can include glucose and ketones tables (e.g., low glucose, normal glucose, high glucose, moderate ketones, high ketones), providing insulin dose amount and carbohydrate amount recommendations for six different conditions (e.g., low glucose-moderate ketones, normal glucose-moderate ketones, high glucose-moderate ketones, low glucose-high ketones, normal glucose-high ketones, high glucose-high ketones). For example, as shown in FIG. 11, for the case of low glucose levels and high ketone levels as in exemplary dose guidance system 1100, dose guidance 374 can provide recommendations 356 to the patient to take 10U of insulin and ingest 5/CR + 15 g of carbohydrates.

[0218] In some aspects, software application 300 (e.g., mobile app) can include a bolus calculator or dose guidance system (referred herein as “dose calculator”) collocated on the mobile app. For example, dose guidance 374 can include a dose calculator. In some aspects, a web-server or cloud server (e.g., remote server 180) supporting software application 300 (e.g., mobile app), located remotely from the mobile app, can include a dose calculator. For example, the remote dose calculator (e.g., on remote server 180) can include an application programming interface (API) that allows software application 300 to retrieve key parameters from the remote dose calculator (e.g., insulin sensitivity, carbohydrate ratio, insulin on board, etc.). In some aspects, software application 300 can retrieve key parameters from a remote dose calculator (e.g., insulin sensitivity, carbohydrate ratio, etc.) and calculate a recommended insulin dose amount and carbohydrate amount for the patient to take, for example, via dose guidance 374. For example, for a low glucose level (e.g., hypoglycemia alarm), software application 300 can recommend consuming carbs to increase glucose levels (e.g., ingest 15 grams to cover low glucose). In some aspects, a remote dose calculator can receive data from software application 300 and calculate a recommended insulin dose amount and carbohydrate amount for the patient to take and send this data (e.g., recommendations) to software application 300. For example, the remote dose calculator (e.g., on remote server 180) can include an API that allows software application 300 to request these outputs

and send analyte data (e.g., glucose level, ketone level, glucose ROC, ketone ROC, time-series data, other derived metrics, etc.) and/or predetermined settings (e.g., glucose and ketone thresholds) as inputs to the remote dose calculator.

[0219] In some aspects, dose guidance 374 can be transmitted to an insulin delivery system (e.g., insulin pump, insulin pen, AID system, IDS 190, etc.) via an API. For example, UI subsystem 344 of software application 300 can provide a confirmation (e.g., response to prompt 358) that the patient intends to initiate the recommended insulin dose and/or carbohydrate amount from dose guidance 374.

[0220] In some aspects, software application 300, with conditional logic (e.g., conditional logic system 310) and corresponding user interface (e.g., UI subsystem 344), can be integrated into the logic and user interface of an IDS (e.g., insulin pump, insulin pen, AID system, IDS 190, etc.), for example, an insulin pump based AID system or an insulin decision support system for multiple daily injection (MDI) or pump. For example, the conditional logic of software application 300 can run concurrently with the IDS or decision support functionality on software application 300, and notifications 352 can be issued asynchronously to the IDS or decision support functionality or buffered and synchronized for display based on priority rules.

[0221] In some aspects, dose guidance 374 can provide a button or indicator that displays an appropriate meal-time dose guidance along with other recommendations based on the detected condition (e.g., glucose-ketone conditional logic). For example, if the recommendation is for the patient to ingest carbs and cover with insulin and the current time is around lunch-time, software application 300 can display a button labeled “lunch” and when selected display the dose guidance for lunch.

[0222] In some aspects, the conditional logic of software application 300 (e.g., glucose-ketone conditional logic) can be integrated with an AID system (e.g., IDS 190) and the conditional logic (e.g., conditional logic system 310) can prevent the AID system from fully suspending insulin delivery, for example, when the patient’s glucose level is low or predicted to be low.

[0223] In some aspects, dose guidance 374 can estimate the amount of insulin needed to either reduce a patient’s glucose to a desired level and/or compensate for an anticipated meal. For example, dose guidance 374 can take into account a current glucose level, a desired glucose level, an estimated insulin-on-board, and/or an estimated anticipated carb intake. In some aspects, dose guidance 374 can assume that the patient’s glycemic response is constant or has different values

during the day. For example, the patient's glycemic response can be characterized by the patient's individual "basal insulin," "insulin sensitivity," and "carb ratio" factors. Basal insulin ("Basal") is the amount of long acting insulin taken during the day (or in the case of insulin pump users, the amount of rapid acting insulin provided continuously), Basal = constant (units per day). Insulin sensitivity ("IS") is the estimated amount of insulin required to lower 1 unit of glucose, IS = constant (mg/dL per unit). Carb ratio ("CR") is the amount of insulin required to compensate for 1 unit of carbohydrate intake, CR = constant (grams per unit). In some aspects, software application 300 can include a glycemic response model (e.g., glycemic response model 376) that is an improvement over a traditional insulin bolus calculator, which is limited to just constant factors (e.g., constant functions).

[0224] Glycemic response model 376 can be configured to provide a recommended dose based on one or more parameters. Glycemic response model 376 can be further configured to enhance a traditional dose calculator by utilizing non-constant factors (e.g., non-constant functions). As shown in FIG. 3, glycemic response model 376 can include dose recommendation 378 and/or parameters 380 (e.g., basal insulin, insulin sensitivity, carb ratio, second analyte). In some aspects, software application 300 can be configured to provide dose recommendation 378 to a patient and/or an IDS (e.g., glucose IDS 190) based on glycemic response model 376.

[0225] In some aspects, glycemic response model 376 can be based on basal insulin (Basal), insulin sensitivity (IS), carbohydrate ratio (CR), and a second analyte. For example, the second analyte can include ketones or lactic acid. In some aspects, the basal insulin, the insulin sensitivity, and/or the carbohydrate ratio can be a function of the second analyte. For example, as shown in FIG. 12, parameters 380, including but not limited to basal insulin (Basal), insulin sensitivity (IS), and carbohydrate ratio (CR), can each be defined as a function of ketone value, $f(\text{Ketones})$, as in exemplary glycemic response model 1200, for example, ketone level, ketone ROC, ketone-based metric, etc.

[0226] In some aspects, glycemic response model 376 can improve a traditional dose calculator (e.g., insulin bolus calculator) by utilizing one or more additional analyte measurements (e.g., ketone, lactic acid, lactate, alcohol) and/or additional information (e.g., basal insulin, insulin sensitivity, carbohydrate ratio). For example, parameters 380 of glycemic response model 376 can include basal insulin (Basal), insulin sensitivity (IS), carbohydrate ratio (CR), and ketone level measurements. In some aspects, glycemic response model 376 can be modified to replace constant

factors (e.g., basal insulin, insulin sensitivity, carbohydrate ratio) of the dose calculation by one or more functions of the second analyte level (e.g., ketone level, time series of ketone levels, ketone rate of change, etc.). For example, as shown in FIG. 12, constant values of basal insulin (Basal), insulin sensitivity (IS), and carbohydrate ratio (CR) can be replaced by a function of ketone level, for example, if ketone level is less than 1.0 mmol/L, then $IS = 4 \text{ mg/dL/U}$; if ketone level is greater than or equal to 1.0 mmol/L but less than 3.0 mmol/L, then $IS = 4 \text{ mg/dL/U} + \{[(\text{ketone level} - 1)/2] \times 4.0 \text{ mmol/L}\} \text{ mg/dL/U}$ [note: 1.0 mmol/L of ketones is about 5.81 mg/dL]; otherwise ketone level = 8 mmol/L.

[0227] In some aspects, glycemic response model 376 can increase an accuracy of a traditional dose calculator (e.g., insulin bolus calculator) by continuously monitoring one or more analytes (e.g., glucose and ketones, lactate, lactic acid, and/or alcohol). For example, software application 300 can perform continuous ketone monitoring to account for dynamic effects of ketones on glycemic response, thereby increasing accuracy of glycemic response model 376.

[0228] Dose recommendation 378 can be configured to recommend a dose to a patient based on glycemic response model 376. As shown in FIG. 3, dose recommendation 378 can be coupled to notification system 350 and provide a dose recommendation to the patient (e.g., recommendation 356) and/or be coupled to IDS control 372 and provide a dose recommendation to an insulin delivery system (e.g., IDS 190). In some aspects, software application 300 can provide (e.g., display) dose recommendation 378 to a patient and/or a clinician or HCP based on glycemic response model 376.

[0229] Parameters 380 can be configured to be utilized in glycemic response model 376 to calculate a recommended dose. Parameters 380 can be configured to be based on non-constant factors and enhance a traditional dose calculator. As shown in FIG. 3, parameters 380 can be coupled to dose recommendation 378 and form key parameters of glycemic response model 376. In some aspects, parameters 380 can include basal insulin (Basal), insulin sensitivity (IS), carbohydrate ratio (CR), and/or a second analyte level (e.g., ketone level, lactic acid level, etc.). In some aspects, parameters 380 can be defined as a function of the second analyte (e.g., ketones, lactate, lactic acid, alcohol). For example, parameters 380, including but not limited to, basal insulin (Basal), insulin sensitivity (IS), and/or carbohydrate ratio (CR), can be defined as a function of ketone value, $f(\text{Ketones})$, for example, ketone level, ketone ROC, ketone-based metric, etc.

[0230] In some aspects, glycemic response model 376 can utilize one or more additional analyte measurements or additional information. For example, parameters 380 can include ketones, lactate, lactic acid, and/or alcohol to enhance a dose calculator of glycemic response model 376 and increase an accuracy of glycemic response model 376. In some aspects, glycemic response model 376 can be based on multiple dose calculators corresponding to one or more additional analyte measurements. For example, glycemic response model 376 can use ketone measurements for a first dose calculator and lactic acid measurements for a second dose calculator.

[0231] In some aspects, glycemic response model 376 can dynamically change parameters 380 to account for dynamic changes in one or more analytes. For example, persistently elevated ketones can be an indicator of reduced insulin sensitivity (IS) and/or increased carbohydrate ratio (CR), requiring more basal insulin (Basal) since more insulin is required when ketones are higher than normal to achieve the same effect on glucose, and glycemic response model 376 can dynamically modify parameters 380 to account for this effect by replacing constant factors with functions based on ketone level. For example, as shown in FIG. 12, basal insulin (Basal) can be defined as a function of ketone value, $\text{Basal} = f(\text{Ketones})$ [units per day], insulin sensitivity (IS) can be defined as a function of ketone value, $\text{IS} = f(\text{Ketones})$ [mg/dL per unit], and carbohydrate ratio (CR) can be defined as a function of ketone value, $\text{CR} = f(\text{Ketones})$ [grams per unit].

[0232] In some aspects, parameters 380 can be defined as a function of ketone value, $f(\text{Ketones})$, with conditional logic. For example, as shown in FIG. 12, parameters 380 can be based on a step-wise linear model as follows:

If ketones < 1.0 mmol/L,

Then $\text{IS} = 4 \text{ mg/dL/Unit}$ (or in common notation, 1:4)

If ketones ≥ 1.0 AND < 3.0 mmol/L,

Then $\text{IS} = 4 + \{(\text{ketone} - 1)/2\} * 4 \text{ mmol/L}$

Otherwise ketones = 8 mmol/L.

[0233] In some aspects, parameters 380 can be defined as a function of more than one ketone measurements or calculations. For example, parameters 380 can be based on a time-series of ketone measurements (e.g., ketone ROC).

[0234] In some aspects, glycemic response model 376 can be based on fitted parameters (e.g., parameters 380) and trained with data from a similar patient population. For example, glycemic

response model 376 can utilize population model 326 and/or predictive algorithm 328 of predictive model 324.

[0235] In some aspects, glycemic response model 376 can be based on an adaptive model (e.g., predictive model 324) starting initially with a populated-trained model and adapting the model over time with the patient's data to further train the model. For example, glycemic response model 376 could track prior insulin dose amounts paired with glucose measurement-derived data (e.g., glucose values at specific time points relative to the insulin dose, glucose ROC at specific time points relative to the insulin dose, area under the curve of glucose above a predetermined threshold for a predetermined time relative to the insulin dose, etc.) and/or ketone measurement-derived data (e.g., ketone values at specific time points relative to the insulin dose, ketone ROC at specific time points relative to the insulin dose, area under the curve of ketones above a predetermined threshold for a predetermined time relative to the insulin dose, etc.).

[0236] In some aspects, glycemic response model 376 can utilize a predetermined model to consider the effect of data prior to an insulin dose on data after the insulin dose. For example, parameters 380 can be updated periodically or recursively to account for this effect (e.g., recursive estimation methods, parameter regression methods, etc.). In some aspects, glycemic response model 376 can utilize data prior to the insulin dose to build features (e.g., subsystems, models, etc.) that can predict certain attributes associated with truth (e.g., conditional logic, truth tables, etc.) based on data after the insulin dose, for example, for every insulin dosing event in the past. For example, the built features can be used in a variety of predictive algorithm (e.g., predictive algorithm 328) or machine learning frameworks to develop an estimator that can update the dosing parameters by accounting for both glucose and ketone derived data, for example, for every insulin dosing decision going forward. In some aspects, glycemic response model 376 can utilize different sets of equations under different conditions, for example, as determined by the glucose and/or ketone derived data. For example, glycemic response model 376 can utilize a machine learning framework (e.g., random forest, predictive algorithm 328, etc.) to provide condition thresholds and equations to determine the insulin dose.

[0237] In some aspects, glycemic response model 376 can be extended to an IDS (e.g., AID system, IDS 190) where insulin is automatically delivered to the patient. For example, glycemic response model 376 can utilize ketone and lactate measurements as inputs for the automatic dose calculator. In some aspects, glycemic response model 376 can utilize multiple models (e.g., for an

AID system) where ketone and lactate measurements can define which model to use. For example, a first model can utilize a lower IS than a second model, and if ketone levels are above a particular threshold, glycemic response model 376 can switch to use the first model that uses a lower IS. In some aspects, glycemic response model 376 can utilize first analyte level 314a (e.g., glucose) and second analyte level 314b (e.g., ketones, lactate, lactic acid, alcohol) to adjust basal insulin delivery, for example, via IDS 190. In some aspects, glycemic response model 376 can utilize first analyte level 314a (e.g., glucose) and second analyte level 314b (e.g., ketones, lactate, lactic acid, alcohol) to adjust bolus dosing, for example, via IDS 190.

[0238] In some aspects, glycemic response model 376 can alter parameters (e.g., parameters 380) and/or switch to a different model based on a patient's response to a prompt (e.g., prompt 358). For example, when software application 300 detects elevated ketones, software application 300 can prompt (e.g., prompt 358) a patient to indicate if the patient is sick or unwell (e.g., request for contextual data 362), and based on the patient's response (e.g., unwell, ill, sick, nauseous, etc.) glycemic response model 376 can alter parameters 380 and/or switch to a different model more appropriate for when the patient is ill.

[0239] In some aspects, glycemic response model 376 can consider lactic acid or lactate as an indicator of a patient's activity, since high activity tends to make glucose reduction more responsive to insulin than normal. For example, lactic acid or lactate can be measured with frequent periodicity and/or a continuous sensor (e.g., analyte sensor 122). In some aspects, glycemic response model 376 can alter parameters (e.g., parameters 380) and/or switch to a different model based on a patient's activity. For example, when software application 300 detects high lactic acid (e.g., indicative of high patient activity), glycemic response model 376 can alter parameters 380 and/or switch to a different model more appropriate for when the patient is conducting high activity to account for the increase in insulin sensitivity (IS).

[0240] In some aspects, glycemic response model 376 can be designed based on a model that simultaneously takes into account any number of additional analyte measurements that may better describe a patient's glycemic response. For example, glycemic response model 376 can include a dose calculator based on one or more analytes, including but not limited to, glucose, ketones, lactate, lactic acid, oxygen, hemoglobin A1C, lactone, lactose, galactose, vitamin C, glucuronate, glycogen, mannose, phosphate, bisphosphate, fructose, glyceraldehyde, glycerol, triglycerides, sorbitol, phosphoglucono, phosphogluconate, xylulose, ribose, bile, cysteine, serine, homoserine,

pyruvate, phenylpyruvate, glutamate, glycine, taurine, threonine, methionine, ethanol, acetone, acetate, oxaloacetate, alanine, phenylalanine, aspartate, asparagine, alcohol, cholesterol, vitamin D, progesterone, testosterone, estrogen, squalene, insulin, hydroxybutyrate, leucine, isoleucine, malonyl, malonate, glucagon, epinephrine, norepinephrine, palmitate, lysine, eicosanoids, melanin, dopamine, tyrosine, tryptophan, niacin, melatonin, serotonin, citrate, isocitrate, valine, porphyrins, histidine, urocanate, histamine, glutamine, proline, creatine, putrescine, spermidine, spermine, arginine, ornithine, citrulline, fumarate, succinate, argininosuccinate, succinyl, ketoglutarate, aconitate, glyoxylate, caffeine, sugars, carbs, or a combination thereof.

[0241] Additional data 382 can be configured to supplement software application 300 and increase accuracy of estimations and/or modeling of software application 300 (e.g., glycemic response model 376, predictive model 324, condition detection 320, etc.). Additional data 382 can be further configured to measure supplemental data with an additional sensor, in addition to analyte sensor 122. As shown in FIG. 3, additional data 382 can be coupled to glycemic response model 376 and/or IDS control 372 to supplement the modeling and/or control instructions.

[0242] In some aspects, software application 300 can be configured to receive data from a second sensor. For example, software application 300 can receive additional data 382 from the second sensor, separate from analyte sensor 122. In some aspects, second sensor can be similar to analyte sensor 122. For example, second sensor can measure one or more analytes of a patient. In some aspects, second sensor can measure additional information of a patient. For example, additional data 382 can include, but is not limited to, activity data, heart rate, breathing rate, body temperature, perspiration data, position data, and/or lactic acid level. In some aspects, additional data 382 from a second sensor can increase an accuracy and precision of estimates of software application 300, for example, detected conditions (e.g., condition detection 320, high ketone conditions), predictive models (e.g., predictive model 324, future analyte levels), and glycemic models (e.g., glycemic response model 376, dose calculators). For example, a predictive model (e.g., predictive model 324, probabilistic model) can be made between additional data 382 (e.g., activity data, heart rate, lactic acid, etc.) and occurrences of high ketone levels to estimate a likelihood of a high ketone condition and present the likelihood to the patient (e.g., notification 352).

[0243] Dose titration 384 can be configured to titrate a dose (e.g., determine amount of constituent in a solution, for example, insulin). Dose titration 384 can be further configured to

automatically titrate a dose of medication for a patient. As shown in FIG. 3, dose titration 384 can be coupled to notification system 350 and provide dose titration guidance to the patient (e.g., recommendation 356) and/or be coupled to IDS control 372 and provide dose titration control instructions to an insulin delivery system (e.g., IDS 190). In some aspects, software application 300 can be configured to titrate a dose based on first analyte level 314a (e.g., glucose) and/or second analyte level 314b (e.g., ketones, lactate, lactic acid, alcohol).

[0244] In some aspects, a medication dose amount (e.g., SGLT-2 inhibitor) can be automatically titrated (e.g., determine amount of constituent in a solution) by dose titration 384 for the patient. In some aspects, dose titration 384 can be based on ketone levels, other analyte levels (e.g., glucose), and/or other measurements (e.g., delivered insulin, carb intake, etc.) to determine if a medication (e.g., SGLT-2 inhibitors) dose amount should be increased, decreased, or maintained. For example, glucose and ketone levels can be processed periodically (e.g., once a month) to determine if the SGLT-2 inhibitors dose amount should be increased, decreased, or maintained, and any change (e.g., recommendation 356) can be displayed to the patient by software application 300 or sent to a clinician or HCP for approval prior to sending to the patient. In some aspects, software application 300 can provide a user interface (e.g., UI subsystem 344) to initiate a report that initiates periodic processing of one or more analyte levels (e.g., glucose and ketone levels) and/or other measurements (e.g., delivered insulin, carb intake, etc.) and displays the result in the report (e.g., reporting 364).

[0245] In some aspects, software application 300 can calculate an analyte variability metric (e.g., glucose standard deviation) and/or a baseline analyte level (e.g., baseline ketone level). For example, software application 300 can retrieve recent glucose and ketone measurement data (e.g., last two weeks) and calculate a standard deviation of the glucose data based on a time period, for example, the entire glucose data, a day-time period, a glucose-time area metric associated with a 5 hour period following each meal, etc., and calculate the median ketone level, filtering out any moderate or high ketone data, to establish a baseline ketone level.

[0246] In some aspects, dose titration 384 can consider the glucose variability and the baseline ketone level and provide a recommendation in a medication dose amount (e.g., SGLT-2 inhibitor). For example, dose titration 384 can recommend an increase in the SGLT-2 inhibitor dose amount if (a) the glucose variability is greater than a predetermined threshold, (b) the baseline ketone level is less than a predetermined threshold, (c) no high ketone levels were recorded over the past year,

and (d) no moderate ketone levels associated with concurrent glucose levels less than a predetermined threshold were recorded over the past year. For example, dose titration 384 can recommend a decrease in the SGLT-2 inhibitor dose amount if (a) the baseline ketone level exceeds a predetermined threshold, or (b) any high ketone levels were recorded over the past year. For example, dose titration 384 can recommend no change in the SGLT-2 inhibitor dose amount if (a) the baseline ketone level is less than a predetermined threshold, and (b) no high ketone levels were recorded over the past year.

[0247] In some aspects, dose titration 384 can include dose parameters and/or titration logic criteria that are configurable. For example, dose titration 384 can include default dose parameter amounts determined or preset by a clinician or HCP or software application 300 can provide a user interface (e.g., UI subsystem 344) to configure or change the dose parameter amounts.

[0248] In some aspects, the software application 300 can export or otherwise output measured ketone data and data related to the measured ketone data. Thus, the user can download ketone data and send the downloaded data to interested caregivers. The data can be exported, printed, or downloaded. For example, the data can be exported to a spreadsheet, which can be attached to an email. As seen in Table 1 below, the exported data may be in the form of a spreadsheet that includes how each of the ketone levels were outputted by the sensor control device, how each of the ketone levels were displayed as a current ketone level on a home screen, e.g., in the banner, how each of the ketone levels were displayed in the graph, the value of each of the ketone levels as saved to a data file, and a notification (if any) associated with each of the ketone levels.

Table 1. Ketone sensor data

Sensor Output	Banner Home Screen Display	Chart Display	Saved Data File Value	Notice Screen
3.1	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
3.2	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
3.3	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
3.4	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
3.5	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
3.6	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
3.7	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
3.8	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
3.9	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.0	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L

4.1	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.2	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.3	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.4	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.5	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.6	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.7	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.8	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
4.9	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
5.0	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
5.1	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
5.2	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
5.3	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
5.4	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
5.5	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
5.6	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L
5.7	>3.0	line at 3.0	3.1	Ketone Level: >3.0 mmol/L

[0249] Exemplary State Diagrams and Display Notifications of Software Application

[0250] FIGS. 4A–10B illustrate state diagrams 400A–1000A and corresponding display notification(s) 400B–1000B for different conditional logic states 10, 20, 30, 40, 50, 60, 70 of software application 300, according to exemplary aspects. State diagrams 400A–1000A can be configured to detect conditional logic states 10, 20, 30, 40, 50, 60, 70 based on predetermined settings (e.g., predetermined settings 332, thresholds 334) and subsequently provide display notification(s) 400B–1000B based on the detected conditional logic state. State diagrams 400A–1000A can be further configured to provide alarms and/or notifications based on one or both analyte levels reaching certain predefined thresholds, and provide a recommendation based on the analyte levels being in certain ranges. State diagrams 400A–1000A can be further configured to request contextual data (e.g., contextual data 362) based on the analyte levels being in certain ranges. Display notification(s) 400B–1000B can be configured to provide custom notifications (e.g., warnings, recommendations, guidance, etc.) to the patient to act based on the different conditional logic states 10, 20, 30, 40, 50, 60, 70. Display notification(s) 400B–1000B can be further configured to prompt the patient for additional information (e.g., contextual data 362) relevant to the detected conditional logic states 10, 20, 30, 40, 50, 60, 70.

[0251] FIGS. 4A and 4B illustrate state diagram 400A and corresponding display notification(s) 400B for first conditional logic state 10 of software application 300, according to an exemplary

aspect. As shown in FIG. 4A, state diagram 400A can include step 402, step 404, step 406, and step 408. In step 402, as shown in FIG. 4A, sensor data 312 can be retrieved (e.g., second analyte level 314b) from analyte measurement system 110 via software application 300 (e.g., conditional logic system 310). In step 404, as shown in FIG. 4A, second analyte level 314b (e.g., ketone level) can be compared to second analyte thresholds 338 (e.g., high ketone threshold of about 3.0 mmol/L) to determine if second analyte level 314b (e.g., ketone level) transitions from below to above a high second analyte threshold 338 (e.g., high ketone threshold of about 3.0 mmol/L), thereby detecting first conditional logic state 10 (e.g., condition detection 320). In step 406, as shown in FIG. 4A, a warning (e.g., warning 354) can be provided to the patient (e.g., via display 140) based on the detected first conditional logic state 10. For example, as shown in FIG. 4B, warning 406b can be displayed on display device 130. In step 408, as shown in FIG. 4A, a recommendation (e.g., recommendation 356) can be provided to the patient (e.g., via display 140) based on the detected first conditional logic state 10. For example, as shown in FIG. 4B, recommendation 408b can be displayed on display device 130.

[0252] In some aspects, display notification 400B can include a button or other input element for the patient to acknowledge and silence display notification 400B, for example, alarm display 156 of display 140. In some aspects, if display notification 400B (e.g., alarm, alert) is ignored, display notification 400B will sound off for a short time period (e.g., about 15 seconds) and then reoccur periodically (e.g., every 15 minutes) until display notification 400B is acknowledged. In some aspects, the above described alarm function is similar for all display notification(s) 400B–1000B.

[0253] In some aspects, display notification 400B (e.g., warning 406b) can continue to display whenever a patient accesses a current analyte reading and/or analyte display in software application 300, for example, a current ketone reading on display 140. In some aspects, display notification 400B can include a button or other input element to display a recommendation (e.g., recommendation 408b) and/or other text associated with first conditional logic state 10, or software application 300 can automatically display the recommendation (e.g., recommendation 408b) and/or other text associated with first conditional logic state 10, for example, on display 140 showing current ketone reading (e.g., numerical display 146) and/or ketone display (e.g., graphical display 142). In some aspects, display notification 400B can include recommended insulin and/or

carbohydrate amounts (e.g., ingest 15 grams of carbs). In some aspects, the above described recommendation function is similar for all display notification(s) 400B–1000B.

[0254] FIGS. 5A and 5B illustrate state diagram 500A and corresponding display notification(s) 500B for second conditional logic state 20 of software application 300, according to an exemplary aspect. As shown in FIG. 5A, state diagram 500A can include step 502, step 504, step 506, and step 508. In step 502, as shown in FIG. 5A, sensor data 312 can be retrieved (e.g., second analyte level 314b) from analyte measurement system 110 via software application 300 (e.g., conditional logic system 310). In step 504, as shown in FIG. 5A, second analyte level 314b (e.g., ketone level) can be compared to second analyte thresholds 338 (e.g., high ketone threshold of about 3.0 mmol/L) to determine if second analyte level 314b (e.g., ketone level) transitions from above to below a high second analyte threshold 338 (e.g., high ketone threshold of about 3.0 mmol/L), thereby detecting second conditional logic state 20 (e.g., condition detection 320). In step 506, as shown in FIG. 5A, a warning (e.g., warning 354) can be provided to the patient (e.g., via display 140) based on the detected second conditional logic state 20. For example, as shown in FIG. 5B, warning 506b can be displayed on display device 130. In step 508, as shown in FIG. 5A, optionally, a prompt (e.g., prompt 358) can be provided to the patient (e.g., via display 140) based on the detected second conditional logic state 20. For example, as shown in FIG. 5B, optionally, prompt 408b can be displayed on display device 130.

[0255] In some aspects, display notification 500B (e.g., warning 506b) will repeat periodically (e.g., every hour) until ketone levels are below a moderate ketone threshold (e.g., about 1.0 mmol/L) for a period of time, for example, 4 hours (e.g., configurable in predetermined settings 332). In some aspects, software application 300 can log or store the patient's answers or selections to prompt 508b (e.g., contextual data 362). For example, once this information is entered and logged (e.g., contextual data 362), display notification 500B can be discontinued until the next time the condition is detected.

[0256] FIGS. 6A and 6B illustrate state diagram 600A and corresponding display notification(s) 600B for third conditional logic state 30 of software application 300, according to an exemplary aspect. As shown in FIG. 6A, state diagram 600A can include step 602, step 604, step 606, step 608, and step 610. In step 602, as shown in FIG. 6A, sensor data 312 can be retrieved (e.g., second analyte level 314b) from analyte measurement system 110 via software application 300 (e.g., conditional logic system 310). In step 604, as shown in FIG. 6A, second analyte level 314b (e.g.,

ketone level) can be compared to second analyte thresholds 338 (e.g., high ketone threshold of about 3.0 mmol/L, low ketone threshold of about 0.5 mmol/L) to determine if second analyte level 314b (e.g., ketone level) transitions from above a high second analyte threshold 338 (e.g., high ketone threshold of about 3.0 mmol/L) to below a low second analyte threshold 338 (e.g., low ketone threshold of about 0.5 mmol/L), thereby detecting third conditional logic state 30 (e.g., condition detection 320). In step 606, as shown in FIG. 6A, a warning (e.g., warning 354) can be provided to the patient (e.g., via display 140) based on the detected third conditional logic state 30. For example, as shown in FIG. 6B, warning 606b (e.g., notification) can be displayed on display device 130 to indicate that ketone levels have recovered. In step 608, as shown in FIG. 6A, a first prompt (e.g., prompt 358) can be provided to the patient (e.g., via display 140) based on the detected third conditional logic state 30. For example, as shown in FIG. 6B, first prompt 608b can be displayed on display device 130. In step 610, as shown in FIG. 6A, a second prompt (e.g., prompt 358) can be provided to the patient (e.g., via display 140) based on the detected third conditional logic state 30. For example, as shown in FIG. 6B, second prompt 610b can be displayed on display device 130.

[0257] In some aspects, if display notification 600B (e.g., first prompt 608b, second prompt 610b) has not been answered, display notification 600B will sound off for a short time period (e.g., about 15 seconds) and then reoccur periodically (e.g., every hour) until display notification 600B is answered. In some aspects, third conditional logic state 30 will only occur after ketone levels have remained below a low ketone threshold (e.g., about 0.5 mmol/L) for a period of time, for example, 2 hours (e.g., configurable in predetermined settings 332). In some aspects, software application 300 can log or store the patient's answers or selections to first prompt 608b and/or second prompt 610b (e.g., contextual data 362). For example, once this information is entered and logged (e.g., contextual data 362), display notification 600B can be discontinued until the next time the condition is detected.

[0258] FIGS. 7A and 7B illustrate state diagram 700A and corresponding display notification(s) 700B for fourth conditional logic state 40 of software application 300, according to an exemplary aspect. As shown in FIG. 7A, state diagram 700A can include step 702, step 704, step 706, and step 708. In step 702, as shown in FIG. 7A, sensor data 312 can be retrieved (e.g., second analyte level 314b) from analyte measurement system 110 via software application 300 (e.g., conditional logic system 310). In step 704, as shown in FIG. 7A, second analyte level 314b (e.g., ketone level)

can be compared to second analyte thresholds 338 (e.g., moderate ketone threshold of about 1.0 mmol/L, low ketone threshold of about 0.5 mmol/L) to determine if second analyte level 314b (e.g., ketone level) transitions from above a moderate second analyte threshold 338 (e.g., moderate ketone threshold of about 1.0 mmol/L) to below a low second analyte threshold 338 (e.g., low ketone threshold of about 0.5 mmol/L), thereby detecting fourth conditional logic state 40 (e.g., condition detection 320). In step 706, as shown in FIG. 7A, a warning (e.g., warning 354) can be provided to the patient (e.g., via display 140) based on the detected fourth conditional logic state 40. For example, as shown in FIG. 7B, warning 706b (e.g., notification) can be displayed on display device 130 to indicate that ketone levels have recovered. In step 708, as shown in FIG. 7A, a prompt (e.g., prompt 358) can be provided to the patient (e.g., via display 140) based on the detected fourth conditional logic state 40. For example, as shown in FIG. 7B, prompt 708b can be displayed on display device 130.

[0259] In some aspects, if display notification 700B (e.g., prompt 708b) has not been answered, display notification 700B will sound off for a short time period (e.g., about 15 seconds) and then reoccur periodically (e.g., every hour) until display notification 700B is answered. In some aspects, software application 300 can log or store the patient's answers or selections to prompt 708b (e.g., contextual data 362). For example, once this information is entered and logged (e.g., contextual data 362), display notification 700B can be discontinued until the next time the condition is detected.

[0260] FIGS. 8A and 8B illustrate state diagram 800A and corresponding display notification(s) 800B for fifth conditional logic state 50 of software application 300, according to an exemplary aspect. As shown in FIG. 8A, state diagram 800A can include step 802, step 804, step 806, step 808, step 810, and step 812. In step 802, as shown in FIG. 8A, sensor data 312 can be retrieved (e.g., first analyte level 314a, second analyte level 314b) from analyte measurement system 110 via software application 300 (e.g., conditional logic system 310). In step 804, as shown in FIG. 8A, second analyte level 314b (e.g., ketone level) can be compared to second analyte thresholds 338 (e.g., high ketone threshold of about 3.0 mmol/L, low ketone threshold of about 0.5 mmol/L) to determine if second analyte level 314b (e.g., ketone level) is below a high second analyte threshold 338 (e.g., high ketone threshold of about 3.0 mmol/L) and above a low second analyte threshold 338 (e.g., low ketone threshold of about 0.5 mmol/L).

[0261] In step 806, as shown in FIG. 8A, (e.g., ketone level is below high ketone threshold and above low ketone threshold), first analyte level 314a (e.g., glucose level) can be compared to first analyte thresholds 336 (e.g., high glucose threshold of about 180 mg/dL) to determine if first analyte level 314a (e.g., glucose level) is above a high first analyte threshold 336 (e.g., high glucose threshold of about 180 mg/dL), thereby detecting fifth conditional logic state 50 (e.g., condition detection 320). In some aspects, step 806 can precede step 804 such that first analyte level 314a (e.g., glucose level) is checked first prior to checking second analyte level 314b (e.g., ketone level). In some aspects, as shown in FIG. 8A, step 804 can precede step 806 such that second analyte level 314b (e.g., ketone level) is checked first prior to checking first analyte level 314a (e.g., glucose level).

[0262] In step 808, as shown in FIG. 8A, a warning (e.g., warning 354) can be provided to the patient (e.g., via display 140) based on the detected fifth conditional logic state 50. For example, as shown in FIG. 8B, warning 808b can be displayed on display device 130. In step 810, as shown in FIG. 8A, a recommendation (e.g., recommendation 356) can be provided to the patient (e.g., via display 140) based on the detected fifth conditional logic state 50. For example, as shown in FIG. 8B, recommendation 810b can be displayed on display device 130. In step 812, as shown in FIG. 8A, a prompt (e.g., prompt 358) can be provided to the patient (e.g., via display 140) based on the detected fifth conditional logic state 50. For example, as shown in FIG. 8B, prompt 812b can be displayed on display device 130.

[0263] In some aspects, display notification 800B (e.g., warning 808b) will repeat periodically (e.g., every 70 minutes) as long as fifth conditional logic state 50 remains unchanged (e.g., ketone level is below high ketone threshold and above low ketone threshold, and glucose level is above high glucose threshold). In some aspects, software application 300 can log or store the patient's answers or selections to prompt 812b (e.g., contextual data 362). For example, once this information is entered and logged (e.g., contextual data 362), display notification 800B can be discontinued until the next time the condition is detected.

[0264] FIGS. 9A and 9B illustrate state diagram 900A and corresponding display notification(s) 900B for sixth conditional logic state 60 of software application 300, according to an exemplary aspect. As shown in FIG. 9A, state diagram 900A can include step 902, step 904, step 906, step 908, step 910, and step 912. In step 902, as shown in FIG. 9A, sensor data 312 can be retrieved (e.g., first analyte level 314a, second analyte level 314b) from analyte measurement system 110

via software application 300 (e.g., conditional logic system 310). In step 904, as shown in FIG. 9A, second analyte level 314b (e.g., ketone level) can be compared to second analyte thresholds 338 (e.g., high ketone threshold of about 3.0 mmol/L, low ketone threshold of about 0.5 mmol/L) to determine if second analyte level 314b (e.g., ketone level) is below a high second analyte threshold 338 (e.g., high ketone threshold of about 3.0 mmol/L) and above a low second analyte threshold 338 (e.g., low ketone threshold of about 0.5 mmol/L).

[0265] In step 906, as shown in FIG. 9A, (e.g., ketone level is below high ketone threshold and above low ketone threshold), first analyte level 314a (e.g., glucose level) can be compared to first analyte thresholds 336 (e.g., high glucose threshold of about 180 mg/dL, low glucose threshold of about 70 mg/dL) to determine if first analyte level 314a (e.g., glucose level) is below a high first analyte threshold 336 (e.g., high glucose threshold of about 180 mg/dL) and above a low first analyte threshold 336 (e.g., low glucose threshold of about 70 mg/dL), thereby detecting sixth conditional logic state 60 (e.g., condition detection 320). In some aspects, step 906 can precede step 904 such that first analyte level 314a (e.g., glucose level) is checked first prior to checking second analyte level 314b (e.g., ketone level). In some aspects, as shown in FIG. 9A, step 904 can precede step 906 such that second analyte level 314b (e.g., ketone level) is checked first prior to checking first analyte level 314a (e.g., glucose level).

[0266] In step 908, as shown in FIG. 9A, a warning (e.g., warning 354) can be provided to the patient (e.g., via display 140) based on the detected sixth conditional logic state 60. For example, as shown in FIG. 9B, warning 908b can be displayed on display device 130. In step 910, as shown in FIG. 9A, a recommendation (e.g., recommendation 356) can be provided to the patient (e.g., via display 140) based on the detected sixth conditional logic state 60. For example, as shown in FIG. 9B, recommendation 910b can be displayed on display device 130. In step 912, as shown in FIG. 9A, a prompt (e.g., prompt 358) can be provided to the patient (e.g., via display 140) based on the detected sixth conditional logic state 60. For example, as shown in FIG. 9B, prompt 912b can be displayed on display device 130.

[0267] In some aspects, display notification 900B (e.g., warning 908b) will repeat periodically (e.g., every 70 minutes) as long as sixth conditional logic state 60 remains unchanged (e.g., ketone level is below high ketone threshold and above low ketone threshold, and glucose level is below high glucose threshold and above low glucose threshold). In some aspects, software application 300 can log or store the patient's answers or selections to prompt 912b (e.g., contextual data 362).

For example, once this information is entered and logged (e.g., contextual data 362), display notification 900B can be discontinued until the next time the condition is detected.

[0268] FIGS. 10A and 10B illustrate state diagram 1000A and corresponding display notification(s) 1000B for seventh conditional logic state 70 of software application 300, according to an exemplary aspect. As shown in FIG. 10A, state diagram 1000A can include step 1002, step 1004, step 1006, step 1008, step 1010, and step 1012. In step 1002, as shown in FIG. 10A, sensor data 312 can be retrieved (e.g., first analyte level 314a, second analyte level 314b) from analyte measurement system 110 via software application 300 (e.g., conditional logic system 310). In step 1004, as shown in FIG. 10A, second analyte level 314b (e.g., ketone level) can be compared to second analyte thresholds 338 (e.g., high ketone threshold of about 3.0 mmol/L, low ketone threshold of about 0.5 mmol/L) to determine if second analyte level 314b (e.g., ketone level) is below a high second analyte threshold 338 (e.g., high ketone threshold of about 3.0 mmol/L) and above a low second analyte threshold 338 (e.g., low ketone threshold of about 0.5 mmol/L).

[0269] In step 1006, as shown in FIG. 10A, (e.g., ketone level is below high ketone threshold and above low ketone threshold), first analyte level 314a (e.g., glucose level) can be compared to first analyte thresholds 336 (e.g., low glucose threshold of about 70 mg/dL) to determine if first analyte level 314a (e.g., glucose level) is below a low first analyte threshold 336 (e.g., low glucose threshold of about 70 mg/dL), thereby detecting seventh conditional logic state 70 (e.g., condition detection 320). In some aspects, step 1006 can precede step 1004 such that first analyte level 314a (e.g., glucose level) is checked first prior to checking second analyte level 314b (e.g., ketone level). In some aspects, as shown in FIG. 10A, step 1004 can precede step 1006 such that second analyte level 314b (e.g., ketone level) is checked first prior to checking first analyte level 314a (e.g., glucose level).

[0270] In step 1008, as shown in FIG. 10A, a warning (e.g., warning 354) can be provided to the patient (e.g., via display 140) based on the detected seventh conditional logic state 70. For example, as shown in FIG. 10B, warning 1008b can be displayed on display device 130. In step 1010, as shown in FIG. 10A, a recommendation (e.g., recommendation 356) can be provided to the patient (e.g., via display 140) based on the detected seventh conditional logic state 70. For example, as shown in FIG. 10B, recommendation 1010b can be displayed on display device 130. In step 1012, as shown in FIG. 10A, a prompt (e.g., prompt 358) can be provided to the patient (e.g., via display

140) based on the detected seventh conditional logic state 70. For example, as shown in FIG. 10B, prompt 1012b can be displayed on display device 130.

[0271] In some aspects, if display notification 1000B (e.g., warning 1008b) is ignored, display notification 1000B will sound off for a short time period (e.g., about 15 seconds) and then repeat periodically (e.g., every 20 minutes) as long as sixth conditional logic state 60 remains unchanged (e.g., ketone level is below high ketone threshold and above low ketone threshold, and glucose level is below low glucose threshold). In some aspects, software application 300 can log or store the patient's answers or selections to prompt 1012b (e.g., contextual data 362). For example, once this information is entered and logged (e.g., contextual data 362), display notification 1000B can be discontinued until the next time the condition is detected.

[0272] It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by those skilled in relevant art(s) in light of the teachings herein.

[0273] The following examples are illustrative, but not limiting, of the aspects of this disclosure. Other suitable modifications and adaptations of the variety of conditions and parameters normally encountered in the field, and which would be apparent to those skilled in the relevant art(s), are within the spirit and scope of the disclosure.

[0274] While specific aspects have been described above, it will be appreciated that the aspects can be practiced otherwise than as described. The description is not intended to limit the scope of the claims.

[0275] It is to be appreciated that the Detailed Description section, and not the Summary and Abstract sections, is intended to be used to interpret the claims. The Summary and Abstract sections may set forth one or more but not all exemplary aspects as contemplated by the inventor(s), and thus, are not intended to limit the aspects and the appended claims in any way.

[0276] The aspects have been described above with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries can be defined so long as the specified functions and relationships thereof are appropriately performed.

[0277] The foregoing description of the specific aspects will so fully reveal the general nature of the aspects that others can, by applying knowledge within the skill of the art, readily modify

and/or adapt for various applications such specific aspects, without undue experimentation, without departing from the general concept of the aspects. Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed aspects, based on the teaching and guidance presented herein.

[0278] The breadth and scope of the aspects should not be limited by any of the above-described exemplary aspects, but should be defined only in accordance with the following claims and their equivalents.

[0279] Various aspects of the present subject matter are set forth below, in review of, and/or in supplementation to, the embodiments described thus far, with the emphasis here being on the interrelation and interchangeability of the following embodiments. In other words, an emphasis is on the fact that each feature of the embodiments can be combined with each and every other feature unless explicitly stated otherwise or logically implausible. The embodiments described herein are restated and expanded upon in the following paragraphs without explicit reference to the figures.

[0280] In many embodiments, a system for continuous ketone monitoring of a subject includes: a sensor control device comprising an in vivo analyte sensor, the in vivo analyte sensor comprising: a proximal portion configured to be positioned above skin of the subject and to be electrically coupled with electronics disposed in an electronics housing of the sensor control device; and a distal portion configured to be transcutaneously positioned through the skin of the subject and in contact with a bodily fluid of the subject, wherein the distal portion of the in vivo analyte sensor is further configured to sense a ketone level in the bodily fluid; a reader device comprising: wireless communication circuitry configured to receive data indicative of the ketone level from the sensor control device; a display; and one or more processors coupled with the wireless communication circuitry, the display, and a memory storing instructions that, when executed by the one or more processors, cause the one or more processors to: display at least one of (1) a current ketone level and an indicator of a current ketone trend based on the data indicative of the ketone level, (2) a ketone trend graph comprising ketone levels for a time period, wherein the ketone levels are based on the data indicative of the ketone level, and (3) a total amount of time that the ketone levels are above at least one predetermined threshold level in the time period; determine if the current ketone level is above the at least one predetermined threshold level; and in response to determining that the current ketone level is above the at least one predetermined threshold level,

output an alarm, wherein the alarm is outputted periodically while the current ketone level is above the at least one predetermined threshold level.

[0281] In some embodiments, the instructions cause the one or more processors to display at least two of: (1) a current ketone level and an indicator of a current ketone trend based on the data indicative of the ketone level, (2) a ketone trend graph comprising ketone levels for a time period, wherein the ketone levels are based on the data indicative of the ketone level, and (3) a total amount of time that the ketone levels are above at least one predetermined threshold level in the time period.

[0282] In some embodiments, the instructions cause the one or more processors to display: (1) a current ketone level and an indicator of a current ketone trend based on the data indicative of the ketone level, (2) a ketone trend graph comprising ketone levels for a time period, wherein the ketone levels are based on the data indicative of the ketone level, and (3) a total amount of time that the ketone levels are above at least one predetermined threshold level in the time period.

[0283] In some embodiments, the alarm is outputted at least about every 5 minutes while the current ketone level is above the at least one predetermined threshold level.

[0284] In some embodiments, the sensor control device comprises wireless communications circuitry configured to periodically transmit the data indicative of the ketone level.

[0285] In some embodiments, the at least one predetermined threshold level is 1.0 mmol/L.

[0286] In some embodiments, the at least one predetermined threshold level comprises a first threshold level and a second threshold level, wherein the first threshold level is 1.0 mmol/L and the second threshold level is 1.5 mmol/L.

[0287] In some embodiments, the at least one predetermined threshold level comprises a first threshold level and a second threshold level that is greater than the first threshold level, wherein the alarm is outputted periodically according to a first time interval while the current ketone level is above the first threshold level, and wherein the alarm is outputted periodically according to a second time interval that is less than the first time interval while the current ketone level is above the second threshold level.

[0288] In some embodiments, the instructions further cause the one or more processors to: determine if a rate of change is above a predetermined rate of change threshold for a second period of time; and output a notification comprising a recommendation to check the subject's ketone level with a blood ketone measurement.

- [0289] In some embodiments, the instructions further cause the one or more processors to output ketone data based on the data indicative of the ketone level to a file.
- [0290] In some embodiments, the in vivo analyte sensor is a ketone sensor.
- [0291] In some embodiments, the ketone data is exported to an email.
- [0292] In some embodiments, the file is an attachment to an email.
- [0293] In some embodiments, the ketone data in the file is arranged according to a plurality of fields, the plurality of fields including a first field associated with the current ketone level.
- [0294] In some embodiments, the plurality of fields further includes a second field associated with the ketone trend graph.
- [0295] In some embodiments, the plurality of fields further includes a third field associated with an alarm notification.
- [0296] In some embodiments, the instructions further cause the one or more processors to output a recommended treatment.
- [0297] In some embodiments, the system further includes a medication delivery device, and the recommended treatment comprises a recommended insulin dose, and wherein the instructions further cause the one or more processors to: output the recommended insulin dose to the medication delivery device.
- [0298] In some embodiments, the instructions further cause the one or more processors to cause the medication delivery device to deliver medication to the subject according to the recommended insulin dose.
- [0299] In some embodiments, if the current ketone level is between about 1.5 mmol/L and 2.5 mmol/L, the instructions further cause the one or more processors to: prompt the subject indicate whether an insulin dose was missed; and in response to an indication that the insulin dose was missed, display a recommendation to administer the insulin dose that was missed and to consume carbohydrates.
- [0300] In some embodiments, if the current ketone level is above about 2.5 mmol/L, the instructions further cause the one or more processors to: prompt the subject to indicate whether an insulin dose was missed; and in response to an indication that the insulin dose was missed, display a recommendation to administer the insulin dose that was missed and to consume carbohydrates.
- [0301] In some embodiments, the instructions further cause the one or more processors to update the current ketone level at least about every minute.

[0302] In some embodiments, the instructions further cause the one or more processors to update the current ketone level at least about every 5 minutes.

[0303] In some embodiments, the instructions further cause the one or more processors to update the ketone trend graph at least about every 5 minutes.

[0304] In some embodiments, the instructions further cause the one or more processors to update the ketone trend graph at least about every 10 minutes.

[0305] In many embodiments, a system includes: an analyte measurement system configured to measure a first analyte and a second analyte of a patient, the analyte measurement system comprising at least one analyte sensor; a processor in communication with the analyte measurement system, wherein the processor is coupled to a memory storing instructions that when executed cause the processor to: retrieve sensor data of first and second analyte levels, and detect at least one condition associated with the sensor data; and an insulin delivery system in communication with the processor, wherein the processor is configured to cause the insulin delivery system to deliver insulin based on the first and second analyte levels.

[0306] In many embodiments, a system includes: an analyte measurement system configured to measure a first analyte and a second analyte of a patient, the analyte measurement system comprising at least one analyte sensor; a processor in communication with the analyte measurement system, wherein the processor is coupled to a memory storing instructions that when executed cause the processor to: retrieve sensor data of first and second analyte levels, and detect at least one condition associated with the sensor data; and an insulin delivery system in communication with the processor, wherein the processor is configured to cause the insulin delivery system to deliver insulin in response to at least one condition being detected.

[0307] In some embodiments, the first analyte comprises glucose and the second analyte comprises ketone.

[0308] In some embodiments, an insulin dose is calculated based on the glucose level, and the calculated insulin dose is further adjusted based on the ketone level.

[0309] In some embodiments, an insulin dose is calculated based on a glycemic response model, wherein inputs in the glycemic response model include basal insulin, insulin sensitivity, and carbohydrate ratio.

[0310] In some embodiments, the insulin sensitivity and/or the carbohydrate ratio are adjusted based on the glucose and ketone levels.

[0311] In some embodiments, the system further includes a display coupled to the processor and configured to visually present information, wherein the processor causes the display to display one or more first trend arrows of the first analyte and one or more second trend arrows of the second analyte.

[0312] In some embodiments, the one or more first trend arrows and the one or more second trend arrows comprise a same number of trend arrows.

[0313] In some embodiments, the one or more first trend arrows and the one or more second trend arrows comprise a different number of trend arrows.

[0314] In some embodiments, the one or more first trend arrows and the one or more second trend arrows display the same rate of change unit of the first and second analytes.

[0315] In some embodiments, the rate of change unit is mmol/L/min.

[0316] In some embodiments, the one or more first trend arrows and the one or more second trend arrows display different rate of change units of the first and second analytes.

[0317] In some embodiments, the one or more first trend arrows comprises a flat arrow to indicate a different rate of change unit for the one or more first trend arrows than for the one or more second trend arrows.

[0318] In some embodiments, the at least one detected condition is an insulin deficiency.

[0319] In some embodiments, the insulin deficiency is caused by an occlusion of the insulin delivery system.

[0320] In some embodiments, the at least one sensor comprises: a proximal portion configured to be positioned above a skin of a subject and to be electrically coupled with electronics disposed in an electronics housing of a sensor control device; and a distal portion configured to be transcutaneously positioned through the skin of the subject and in contact with a bodily fluid of the subject, wherein the distal portion of the sensor is further configured to sense at least one of the first analyte and the second analyte in the bodily fluid.

[0321] In some embodiments, the at least one sensor comprises a first sensor configured to measure the first analyte and a second sensor configured to measure the second analyte.

[0322] In some embodiments, the at least one sensor comprises a single sensor configured to measure the first and second analyte.

[0323] In some embodiments, the single sensor comprises a first sensing region configured to measure the first analyte and a second sensing region configured to measure the second analyte.

[0324] In many embodiments, a system includes: an analyte measurement system configured to measure a first analyte and a second analyte of a patient, the analyte measurement system comprising an analyte sensor and a display device; and a processor in communication with the analyte measurement system, wherein the processor is coupled to a memory storing instructions that when executed cause the processor to: retrieve sensor data of first and second analyte levels, detect at least one condition associated with the sensor data, provide a notification to the patient associated with the at least one detected condition, prompt the patient to enter contextual data, wherein the contextual data is associated with the at least one detected condition, save a record of the at least one detected condition along with the contextual data, and generate a report comprising the at least one detected condition and associated contextual data.

[0325] In some embodiments, the processor is configured to operate on conditional logic associated with predetermined settings.

[0326] In some embodiments, the processor is configured to adjust the predetermined settings.

[0327] In some embodiments, the predetermined settings comprise a first threshold value of the first analyte and a second threshold value of the second analyte.

[0328] In some embodiments, the predetermined settings comprise first and second threshold values of the first analyte and third and fourth threshold values of the second analyte.

[0329] In some embodiments, the processor is configured to adjust the conditional logic based on a rate of change of the first analyte level and/or the second analyte level.

[0330] In some embodiments, the processor is configured to adjust the conditional logic based on insulin sensitivity, carbohydrate ratio, patient disease state, patient medication regimen, and/or pairing with a remote dose system.

[0331] In some embodiments, the first and second analytes are measured continuously in real-time.

[0332] In some embodiments, the first analyte is measured at a different frequency than the second analyte.

[0333] In some embodiments, the analyte sensor comprises a dual analyte sensor to measure the first and second analytes.

[0334] In some embodiments, the analyte sensor comprises two separate analyte sensors to measure the first and second analytes.

[0335] In some embodiments, the first analyte comprises glucose and the second analyte comprises ketone.

[0336] In some embodiments, the analyte sensor includes: a proximal portion configured to be positioned above a skin of a subject and to be electrically coupled with electronics disposed in an electronics housing of a sensor control device; and a distal portion configured to be transcutaneously positioned through the skin of the subject and in contact with a bodily fluid of the subject, wherein the distal portion of the sensor is further configured to sense at least one of the first analyte and the second analyte in the bodily fluid.

[0337] In some embodiments, the analyte measurement system comprises at least one sensor control device comprising a housing and wireless communication circuitry disposed in the housing configured to transmit the sensor data of the first and the second analyte levels.

[0338] In some embodiments, the system further includes an insulin delivery system operatively coupled to the processor, wherein the processor is configured to control the insulin delivery system based on the at least one detected condition.

[0339] In some embodiments, the processor is configured to cause continuation of insulin delivery if the ketone level is above a high ketone threshold.

[0340] In some embodiments, the notification comprises a warning to the patient associated with the at least one detected condition.

[0341] In some embodiments, the notification comprises a recommendation for the patient to act associated with the at least one detected condition.

[0342] In some embodiments, the processor is configured to provide a second notification to the patient if the at least one detected condition remains unchanged after a predetermined time period.

[0343] In some embodiments, the processor is configured to adjust a threshold value of the first analyte and/or the second analyte based on the contextual data.

[0344] In some embodiments, the contextual data comprises a frequency of the at least one detected condition. In some embodiments, the frequency comprises a number of times the at least one detected condition occurs in at least one of 1 hour, 6 hours, 12 hours, a day, a week, a month, or a combination thereof.

[0345] In some embodiments, the contextual data comprises a discomfort level of the patient.

[0346] In some embodiments, the contextual data comprises at least one of contributing factors of the patient, medications taken by the patient, whether the patient received emergency medical services, or a combination thereof.

[0347] In some embodiments, the processor is configured to perform analytics of the sensor data to determine a baseline first analyte level and/or a baseline second analyte level.

[0348] In some embodiments, the processor is configured to perform analytics of the sensor data to determine a predictive model. In some embodiments, the predictive model is based on a population model and one or more parameters that modulate the predictive model into a range of known variations from the population model. In some embodiments, the predictive model is based on at least one of regression, model-based parameter adaptation, supervised machine learning, unsupervised machine learning, neural networks, classification models, or a combination thereof.

[0349] In some embodiments, the system further includes a dose guidance system operatively coupled to the processor.

[0350] In some embodiments, the processor is configured to provide a dose recommendation based on a glycemic response model. In some embodiments, the glycemic response model is based on basal insulin, insulin sensitivity, carbohydrate ratio, and the second analyte.

[0351] In some embodiments, the second analyte comprises ketone or lactic acid.

[0352] In some embodiments, the basal insulin, the insulin sensitivity, and/or the carbohydrate ratio is a function of the second analyte.

[0353] In some embodiments, the processor is configured to retrieve additional data from a second sensor. In some embodiments, the additional data comprises at least one of activity data, heart rate, breathing rate, body temperature, perspiration data, position data, and/or lactic acid level.

[0354] In some embodiments, the processor is configured to titrate a dose based on the first analyte level and/or the second analyte level.

[0355] In some embodiments, the processor is configured to determine an erroneous reading based on the first analyte level and/or the second analyte level.

[0356] In some embodiments, the processor is part of the analyte measurement system.

[0357] In some embodiments, the processor comprises a mobile application on the display device.

[0358] In some embodiments, the system further includes a remote server configured to support the processor.

[0359] In some embodiments, the processor is configured to change a default home screen of the display device based on the at least one detected condition.

[0360] In many embodiments, a method includes: measuring a first analyte and a second analyte of a patient with an analyte measurement system, the analyte measurement system comprising an analyte sensor and a display device; retrieving sensor data of first and second analyte levels with a processor in communication with the analyte measurement system; detecting at least one condition associated with the sensor data; and providing a notification to the patient associated with the at least one detected condition.

[0361] In some embodiments, the method further includes the step of providing a prompt to the patient to retrieve additional information regarding the at least one detected condition.

[0362] In some embodiments, detecting comprises utilizing conditional logic associated with predetermined settings.

[0363] In some embodiments, the predetermined settings comprise first and second threshold values of the first analyte and third and fourth threshold values of the second analyte.

[0364] In some embodiments, measuring comprises continuously measuring the first and second analytes in real-time.

[0365] In many embodiments, a sensor includes a proximal portion configured to be positioned above a skin of a subject and to be electrically coupled with electronics disposed in an electronics housing of a sensor control device; and a distal portion configured to be transcutaneously positioned through the skin of the subject and in contact with a bodily fluid of the subject, wherein the distal portion of the sensor is further configured to sense at least one of the first analyte and the second analyte in the bodily fluid.

[0366] In many embodiments, a sensor includes a proximal portion configured to be positioned above a skin of a subject and to be electrically coupled with electronics disposed in an electronics housing of a sensor control device; and a distal portion configured to be transcutaneously positioned through the skin of the subject and in contact with a bodily fluid of the subject, wherein the distal portion of the sensor is further configured to sense at least one analyte in the bodily fluid.

Clauses

The present invention may also be described in accordance with the following clauses:

Clause 1. A system comprising:

an analyte measurement system configured to measure a first analyte and a second analyte of a patient, the analyte measurement system comprising an analyte sensor and a display device; and

a processor in communication with the analyte measurement system, wherein the processor is coupled to a memory storing instructions that when executed cause the processor to:

retrieve sensor data of first and second analyte levels,

detect at least one condition associated with the sensor data,

provide a notification to the patient associated with the at least one detected condition,

prompt the patient to enter contextual data, wherein the contextual data is associated with the at least one detected condition,

save a record of the at least one detected condition along with the contextual data, and

generate a report comprising the at least one detected condition and associated contextual data.

Clause 2. The system of clause 1, wherein the processor is configured to operate on conditional logic associated with predetermined settings.

Clause 3. The system of clause 2, wherein the processor is configured to adjust the predetermined settings.

Clause 4. The system of clause 2 or clause 3, wherein the predetermined settings comprise a first threshold value of the first analyte and a second threshold value of the second analyte.

Clause 5. The system of clause 2 or clause 3, wherein the predetermined settings comprise first and second threshold values of the first analyte and third and fourth threshold values of the second analyte.

Clause 6. The system of any one of clauses 2 to 5, wherein the processor is configured to adjust the conditional logic based on a rate of change of the first analyte level and/or the second analyte level.

Clause 7. The system of any one of clauses 2 to 6, wherein the processor is configured to adjust the conditional logic based on insulin sensitivity, carbohydrate ratio, patient disease state, patient medication regimen, and/or pairing with a remote dose system.

Clause 8. The system of any one of clauses 1 to 7, wherein the first and second analytes are measured continuously in real-time.

Clause 9. The system of any one of clauses 1 to 8, wherein the first analyte is measured at a different frequency than the second analyte.

Clause 10. The system of any one of clauses 1 to 9, wherein the analyte sensor comprises a dual analyte sensor to measure the first and second analytes.

Clause 11. The system of any one of clauses 1 to 9, wherein the analyte sensor comprises two separate analyte sensors to measure the first and second analytes.

Clause 12. The system of any one of clauses 1 to 11, wherein the first analyte comprises glucose and the second analyte comprises ketone.

Clause 13. The system of clause 12, further comprising an insulin delivery system operatively coupled to the processor, wherein the processor is configured to control the insulin delivery system based on the at least one detected condition.

Clause 14. The system of clause 13, wherein the processor is configured to cause continuation of insulin delivery if the ketone level is above a high ketone threshold.

Clause 15. The system of any one of clauses 1 to 14, wherein the notification comprises a warning to the patient associated with the at least one detected condition.

Clause 16. The system of any one of clauses 1 to 15, wherein the notification comprises a recommendation for the patient to act associated with the at least one detected condition.

Clause 17. The system of any one of clauses 1 to 16, wherein the processor is configured to provide a second notification to the patient if the at least one detected condition remains unchanged after a predetermined time period.

Clause 18. The system of any one of clauses 1 to 17, wherein the processor is configured to adjust a threshold value of the first analyte and/or the second analyte based on the contextual data.

Clause 19. The system of any one of clauses 1 to 18, wherein the contextual data comprises a frequency of the at least one detected condition.

Clause 20. The system of clause 19, wherein the frequency comprises a number of times the at least one detected condition occurs in 1 hour, 6 hours, 12 hours, a day, a week, a month, or a combination thereof.

Clause 21. The system of any one of clauses 1 to 20, wherein the contextual data comprises a discomfort level of the patient.

Clause 22. The system of any one of clauses 1 to 21, wherein the contextual data comprises contributing factors of the patient, medications taken by the patient, whether the patient received emergency medical services, or a combination thereof.

Clause 23. The system of any one of clauses 1 to 22, wherein the processor is configured to perform analytics of the sensor data to determine a baseline first analyte level and/or a baseline second analyte level.

Clause 24. The system of any one of clauses 1 to 23, wherein the processor is configured to perform analytics of the sensor data to determine a predictive model.

Clause 25. The system of clause 24, wherein the predictive model is based on a population model and one or more parameters that modulate the predictive model into a range of known variations from the population model.

Clause 26. The system of clause 25, wherein the predictive model is based on regression, model-based parameter adaptation, supervised machine learning, unsupervised machine learning, neural networks, classification models, or a combination thereof.

Clause 27. The system of any one of clauses 1 to 26, further comprising a dose guidance system operatively coupled to the processor.

Clause 28. The system of any one of clauses 1 to 27, wherein the processor is configured to provide a dose recommendation based on a glycemic response model.

Clause 29. The system of clause 28, wherein the glycemic response model is based on basal insulin, insulin sensitivity, carbohydrate ratio, and the second analyte.

Clause 30. The system of any one of clauses 1 to 29, wherein the second analyte comprises ketone or lactic acid.

Clause 31. The system of clause 29 or clause 30 when dependent on clause 29, wherein the basal insulin, the insulin sensitivity, and/or the carbohydrate ratio is a function of the second analyte.

Clause 32. The system of any one of clauses 1 to 31, wherein the processor is configured to retrieve additional data from a second sensor.

Clause 33. The system of clause 32, wherein the additional data comprises activity data, heart rate, breathing rate, body temperature, perspiration data, position data, and/or lactic acid level.

Clause 34. The system of any one of clauses 1 to 33, wherein the processor is configured to titrate a dose based on the first analyte level and/or the second analyte level.

Clause 35. The system of any one of clauses 1 to 34, wherein the processor is configured to determine an erroneous reading based on the first analyte level and/or the second analyte level.

Clause 36. The system of any one of clauses 1 to 35, wherein the processor is part of the analyte measurement system.

Clause 37. The system of any one of clause 1 to 36, wherein the processor comprises a mobile application on the display device.

Clause 38. The system of any one of clauses 1 to 37, further comprising a remote server configured to support the processor.

Clause 39. The system of any one of clauses 1 to 38, wherein the processor is configured to change a default home screen of the display device based on the at least one detected condition.

Clause 40. A method comprising:

measuring a first analyte and a second analyte of a patient with an analyte measurement system, the analyte measurement system comprising an analyte sensor and a display device;

retrieving sensor data of first and second analyte levels with a processor in communication with the analyte measurement system;

detecting at least one condition associated with the sensor data; and

providing a notification to the patient associated with the at least one detected condition.

Clause 41. The method of clause 40, further comprising providing a prompt to the patient to retrieve additional information regarding the at least one detected condition.

Clause 42. The method of clause 40 or clause 41, wherein detecting comprises utilizing conditional logic associated with predetermined settings.

Clause 43. The method of clause 42, wherein the predetermined settings comprise first and second threshold values of the first analyte and third and fourth threshold values of the second analyte.

Clause 44. The method of any one of clauses 40 to 43, wherein measuring comprises continuously measuring the first and second analytes in real-time.

Clause 45. A system comprising:

an analyte measurement system configured to measure a first analyte and a second analyte of a patient, the analyte measurement system comprising an analyte sensor;

a processor in communication with the analyte measurement system, wherein the processor is coupled to a memory storing instructions that when executed cause the processor to:

retrieve sensor data of first and second analyte levels, and

detect at least one condition associated with the sensor data; and

an insulin delivery system in communication with the processor, wherein the processor is configured to cause the insulin delivery system to deliver insulin based on the first and second analyte levels.

Clause 46. The system of clause 45, wherein the first analyte comprises glucose and the second analyte comprises ketone.

Clause 47. The system of clause 46, wherein an insulin dose is calculated based on the glucose level, and the calculated insulin dose is further adjusted based on the ketone level.

Clause 48. The system of clause 46 or clause 47, wherein an insulin sensitivity and/or a carbohydrate ratio are adjusted based on the glucose and ketone levels.

Clause 49. The system of any one of clauses 45 to 48, further comprising a display configured to display one or more first trend arrows of the first analyte and one or more second trend arrows of the second analyte.

Clause 50. The system of clause 49, wherein the one or more first trend arrows and the one or more second trend arrows comprise the same number of trend arrows.

Clause 51. The system of clause 49, wherein the one or more first trend arrows and the one or more second trend arrows comprise a different number of trend arrows.

Clause 52. The system of any one of clauses 49 to 51, wherein the one or more first trend arrows and the one or more second trend arrows display the same rate of change unit of the first and second analytes.

Clause 53. The system of clause 52, wherein the rate of change unit is mmol/L/min.

Clause 54. The system of any one of clauses 49 to 51, wherein the one or more first trend arrows and the one or more second trend arrows display different rate of change units of the first and second analytes.

Clause 55. The system of clause 54, wherein the one or more first trend arrows comprises a flat arrow to indicate a different rate of change unit for the one or more first trend arrows than for the one or more second trend arrows.

Clause 56. A system for continuous ketone monitoring of a subject, the system comprising:

- a sensor control device comprising an in vivo analyte sensor, the in vivo analyte sensor comprising:

- a proximal portion configured to be positioned above skin of the subject and to be electrically coupled with electronics disposed in an electronics housing of the sensor control device; and

- a distal portion configured to be transcutaneously positioned through the skin of the subject and in contact with a bodily fluid of the subject, wherein the distal portion of the in vivo analyte sensor is further configured to sense a ketone level in the bodily fluid;

- a reader device comprising:

- wireless communication circuitry configured to receive data indicative of the ketone level from the sensor control device;

- a display; and

- one or more processors coupled with the wireless communication circuitry, the display, and a memory storing instructions that, when executed by the one or more processors, cause the one or more processors to:

display at least one of (1) a current ketone level and an indicator of a current ketone trend based on the data indicative of the ketone level, (2) a ketone trend graph comprising ketone levels for a time period, wherein the ketone levels are based on the data indicative of the ketone level, and (3) a total amount of time that the ketone levels are above at least one predetermined threshold level in the time period;

determine if the current ketone level is above the at least one predetermined threshold level; and

in response to determining that the current ketone level is above the at least one predetermined threshold level, output an alarm, wherein the alarm is outputted periodically while the current ketone level is above the at least one predetermined threshold level.

Clause 57. The system of clause 56, wherein the alarm is outputted at least about every 5 minutes while the current ketone level is above the at least one predetermined threshold level.

Clause 58. The system of any of clauses 56-57, wherein the sensor control device comprises wireless communications circuitry configured to periodically transmit the data indicative of the ketone level.

Clause 59. The system of any of clauses 56-57, wherein the at least one predetermined threshold level is 1.0 mmol/L.

Clause 60. The system of any of clauses 56-59, wherein the at least one predetermined threshold level comprises a first threshold level and a second threshold level, wherein the first threshold level is 1.0 mmol/L and the second threshold level is 1.5 mmol/L.

Clause 61. The system of any of clauses 56-60, wherein the at least one predetermined threshold comprises a first threshold level and a second threshold level that is greater than the first threshold level, wherein the alarm is outputted periodically according to a first time interval while the current ketone level is above the first threshold level, and wherein the alarm is outputted periodically according to a second time interval that is less than the first time interval while the current ketone level is above the second threshold level.

Clause 62. The system of any of clauses 56-61, wherein the instructions further cause the one or more processors to:

determine if a rate of change is above a predetermined rate of change threshold for a

second period of time; and

output a notification comprising a recommendation to check the subject's ketone level with a blood ketone measurement.

Clause 63. The system of any of clauses 56-62, wherein the instructions further cause the one or more processors to:

output ketone data based on the data indicative of the ketone level to a file.

Clause 64. The system of any of clauses 56-63, wherein the in vivo analyte sensor is a ketone sensor.

Clause 65. The system of clause 64, wherein the ketone data is exported to an email.

Clause 66. The system of clause 63 or 65, wherein the file is an attachment to an email.

Clause 67. The system of clause 63, 65, or 66, wherein the ketone data in the file is arranged according to a plurality of fields, the plurality of fields including a first field associated with the current ketone level.

Clause 68. The system of clause 67, wherein the plurality of fields further includes a second field associated with the ketone trend graph.

Clause 69. The system of any of clauses 67-68, wherein the plurality of fields further includes a third field associated with an alarm notification.

Clause 70. The system of any of clauses 56-69, wherein the instructions further cause the one or more processors to:

output a recommended treatment.

Clause 71. The system of clause 70, further comprising a medication delivery device, wherein the recommended treatment comprises a recommended insulin dose, and wherein the instructions further cause the one or more processors to:

output the recommended insulin dose to the medication delivery device.

Clause 72. The system of clause 71, wherein the instructions further cause the one or more processors to:

cause the medication delivery device to deliver medication to the subject according to the recommended insulin dose.

Clause 73. The system of any of clauses 70-72, wherein, if the current ketone level is between about 1.5 mmol/L and 2.5 mmol/L, the instructions further cause the one or more

processors to:

prompt the subject to indicate whether an insulin dose was missed; and
in response to an indication that the insulin dose was missed, display a recommendation to administer the insulin dose that was missed and to consume carbohydrates.

Clause 74. The system of any of clauses 70-73, wherein if the current ketone level is above about 2.5 mmol/L, the instructions further cause the one or more processors to:

prompt the subject to indicate whether an insulin dose was missed; and
in response to an indication that the insulin dose was missed, display a recommendation to administer the insulin dose that was missed and to consume carbohydrates.

Clause 75. The system of any of clauses 56-74, wherein the instructions further cause the one or more processors to:

update the current ketone level at least about every minute.

Clause 76. The system of any of clauses 56-75, wherein the instructions further cause the one or more processors to:

update the current ketone level at least about every 5 minutes.

Clause 77. The system of any of clauses 56-76, wherein the instructions further cause the one or more processors to:

update the ketone trend graph at least about every 5 minutes.

Clause 78. The system of any of clauses 56-77, wherein the instructions further cause the one or more processors to:

update the ketone trend graph at least about every 10 minutes.

WHAT IS CLAIMED IS:

1. A system for continuous ketone monitoring of a subject, the system comprising:
a sensor control device comprising an in vivo analyte sensor, the in vivo analyte sensor comprising:
a proximal portion configured to be positioned above skin of the subject and to be electrically coupled with electronics disposed in an electronics housing of the sensor control device; and
a distal portion configured to be transcutaneously positioned through the skin of the subject and in contact with a bodily fluid of the subject, wherein the distal portion of the in vivo analyte sensor is further configured to sense a ketone level in the bodily fluid;
a reader device comprising:
wireless communication circuitry configured to receive data indicative of the ketone level from the sensor control device;
a display; and
one or more processors coupled with the wireless communication circuitry, the display, and a memory storing instructions that, when executed by the one or more processors, cause the one or more processors to:
display at least one of (1) a current ketone level and an indicator of a current ketone trend based on the data indicative of the ketone level, (2) a ketone trend graph comprising ketone levels for a time period, wherein the ketone levels are based on the data indicative of the ketone level, and (3) a total amount of time that the ketone levels are above at least one predetermined threshold level in the time period;
determine if the current ketone level is above the at least one predetermined threshold level; and
in response to determining that the current ketone level is above the at least one predetermined threshold level, output an alarm, wherein the alarm is outputted periodically while the current ketone level is above the at least one predetermined threshold level.

2. The system of claim 1, wherein the alarm is outputted at least about every 5 minutes while the current ketone level is above the at least one predetermined threshold level.

3. The system of claim 1, wherein the sensor control device comprises wireless communications circuitry configured to periodically transmit the data indicative of the ketone level.

4. The system of claim 1, wherein the at least one predetermined threshold level is 1.0 mmol/L.

5. The system of claim 1, wherein the at least one predetermined threshold level comprises a first threshold level and a second threshold level, wherein the first threshold level is 1.0 mmol/L and the second threshold level is 1.5 mmol/L.

6. The system of claim 1, wherein the at least one predetermined threshold level comprises a first threshold level and a second threshold level that is greater than the first threshold level, wherein the alarm is outputted periodically according to a first time interval while the current ketone level is above the first threshold level, and wherein the alarm is outputted periodically according to a second time interval that is less than the first time interval while the current ketone level is above the second threshold level.

7. The system of claim 1, wherein the instructions further cause the one or more processors to:

determine if a rate of change is above a predetermined rate of change threshold for a second period of time; and

output a notification comprising a recommendation to check the subject's ketone level with a blood ketone measurement.

8. The system of claim 1, wherein the instructions further cause the one or more processors to:

output ketone data based on the data indicative of the ketone level to a file.

9. The system of claim 1, wherein the in vivo analyte sensor is a ketone sensor.

10. The system of claim 8, wherein the ketone data is exported to an email.

11. The system of claim 8, wherein the file is an attachment to an email.
12. The system of claim 8, wherein the ketone data in the file is arranged according to a plurality of fields, the plurality of fields including a first field associated with the current ketone level.
13. The system of claim 12, wherein the plurality of fields further includes a second field associated with the ketone trend graph.
14. The system of claim 12, wherein the plurality of fields further includes a third field associated with an alarm notification.
15. The system of claim 1, wherein the instructions further cause the one or more processors to:
output a recommended treatment.
16. The system of claim 15, further comprising a medication delivery device, wherein the recommended treatment comprises a recommended insulin dose, and wherein the instructions further cause the one or more processors to:
output the recommended insulin dose to the medication delivery device.
17. The system of claim 16, wherein the instructions further cause the one or more processors to:
cause the medication delivery device to deliver medication to the subject according to the recommended insulin dose.
18. The system of claim 15, wherein, if the current ketone level is between about 1.5 mmol/L and 2.5 mmol/L, the instructions further cause the one or more processors to:
prompt the subject to indicate whether an insulin dose was missed; and
in response to an indication that the insulin dose was missed, display a recommendation to administer the insulin dose that was missed and to consume carbohydrates.
19. The system of claim 15, wherein if the current ketone level is above about 2.5 mmol/L, the instructions further cause the one or more processors to:
prompt the subject to indicate whether an insulin dose was missed; and

in response to an indication that the insulin dose was missed, display a recommendation to administer the insulin dose that was missed and to consume carbohydrates.

20. The system of claim 1, wherein the instructions further cause the one or more processors to:

update the current ketone level at least about every minute.

21. The system of claim 1, wherein the instructions further cause the one or more processors to:

update the current ketone level at least about every 5 minutes.

22. The system of claim 1, wherein the instructions further cause the one or more processors to:

update the ketone trend graph at least about every 5 minutes.

23. The system of claim 1, wherein the instructions further cause the one or more processors to:

update the ketone trend graph at least about every 10 minutes.

24. A system comprising:

an analyte measurement system configured to measure a first analyte and a second analyte of a patient, the analyte measurement system comprising an analyte sensor and a display device; and

a processor in communication with the analyte measurement system, wherein the processor is coupled to a memory storing instructions that when executed cause the processor to:

retrieve sensor data of first and second analyte levels,

detect at least one condition associated with the sensor data,

provide a notification to the patient associated with the at least one detected condition,

prompt the patient to enter contextual data, wherein the contextual data is associated with the at least one detected condition,

save a record of the at least one detected condition along with the contextual data,

and

generate a report comprising the at least one detected condition and associated contextual data.

25. The system of claim 24, wherein the processor is configured to operate on conditional logic associated with predetermined settings.

26. The system of claim 25, wherein the processor is configured to adjust the predetermined settings.

27. The system of claim 25, wherein the predetermined settings comprise a first threshold value of the first analyte and a second threshold value of the second analyte.

28. The system of claim 25, wherein the predetermined settings comprise first and second threshold values of the first analyte and third and fourth threshold values of the second analyte.

29. The system of claim 25, wherein the processor is configured to adjust the conditional logic based on a rate of change of the first analyte level and/or the second analyte level.

30. The system of claim 25, wherein the processor is configured to adjust the conditional logic based on insulin sensitivity, carbohydrate ratio, patient disease state, patient medication regimen, and/or pairing with a remote dose system.

31. The system of claim 24, wherein the first and second analytes are measured continuously in real-time.

32. The system of claim 24, wherein the first analyte is measured at a different frequency than the second analyte.

33. The system of claim 24, wherein the analyte sensor comprises a dual analyte sensor to measure the first and second analytes.

34. The system of claim 24, wherein the analyte sensor comprises two separate analyte sensors to measure the first and second analytes.

35. The system of claim 24, wherein the first analyte comprises glucose and the second analyte comprises ketone.

36. The system of claim 35, further comprising an insulin delivery system operatively coupled to the processor, wherein the processor is configured to control the insulin delivery system based on the at least one detected condition.

37. The system of claim 36, wherein the processor is configured to cause continuation of insulin delivery if the ketone level is above a high ketone threshold.

38. The system of claim 24, wherein the notification comprises a warning to the patient associated with the at least one detected condition.

39. The system of claim 24, wherein the notification comprises a recommendation for the patient to act associated with the at least one detected condition.

40. The system of claim 24, wherein the processor is configured to provide a second notification to the patient if the at least one detected condition remains unchanged after a predetermined time period.

41. The system of claim 24, wherein the processor is configured to adjust a threshold value of the first analyte and/or the second analyte based on the contextual data.

42. The system of claim 24, wherein the contextual data comprises a frequency of the at least one detected condition.

43. The system of claim 42, wherein the frequency comprises a number of times the at least one detected condition occurs in 1 hour, 6 hours, 12 hours, a day, a week, a month, or a combination thereof.

44. The system of claim 24, wherein the contextual data comprises a discomfort level of the patient.

45. The system of claim 24, wherein the contextual data comprises contributing factors of the patient, medications taken by the patient, whether the patient received emergency medical services, or a combination thereof.

46. The system of claim 24, wherein the processor is configured to perform analytics of the sensor data to determine a baseline first analyte level and/or a baseline second analyte level.

47. The system of claim 24, wherein the processor is configured to perform analytics of the sensor data to determine a predictive model.

48. The system of claim 47, wherein the predictive model is based on a population model and one or more parameters that modulate the predictive model into a range of known variations from the population model.

49. The system of claim 48, wherein the predictive model is based on regression, model-based parameter adaptation, supervised machine learning, unsupervised machine learning, neural networks, classification models, or a combination thereof.

50. The system of claim 24, further comprising a dose guidance system operatively coupled to the processor.

51. The system of claim 24, wherein the processor is configured to provide a dose recommendation based on a glycemic response model.

52. The system of claim 51, wherein the glycemic response model is based on basal insulin, insulin sensitivity, carbohydrate ratio, and the second analyte.

53. The system of claim 52, wherein the second analyte comprises ketone or lactic acid.

54. The system of claim 52, wherein the basal insulin, the insulin sensitivity, and/or the carbohydrate ratio is a function of the second analyte.

55. The system of claim 24, wherein the processor is configured to retrieve additional data from a second sensor.

56. The system of claim 55, wherein the additional data comprises activity data, heart rate, breathing rate, body temperature, perspiration data, position data, and/or lactic acid level.

57. The system of claim 24, wherein the processor is configured to titrate a dose based on the first analyte level and/or the second analyte level.

58. The system of claim 24, wherein the processor is configured to determine an erroneous reading based on the first analyte level and/or the second analyte level.

59. The system of claim 24, wherein the processor is part of the analyte measurement system.

60. The system of claim 24, wherein the processor comprises a mobile application on the display device.

61. The system of claim 24, further comprising a remote server configured to support the processor.

62. The system of claim 24, wherein the processor is configured to change a default home screen of the display device based on the at least one detected condition.

63. A method comprising:
measuring a first analyte and a second analyte of a patient with an analyte measurement system, the analyte measurement system comprising an analyte sensor and a display device;
retrieving sensor data of first and second analyte levels with a processor in communication with the analyte measurement system;
detecting at least one condition associated with the sensor data; and
providing a notification to the patient associated with the at least one detected condition.

64. The method of claim 63, further comprising providing a prompt to the patient to retrieve additional information regarding the at least one detected condition.

65. The method of claim 63, wherein detecting comprises utilizing conditional logic associated with predetermined settings.

66. The method of claim 65, wherein the predetermined settings comprise first and second threshold values of the first analyte and third and fourth threshold values of the second analyte.

67. The method of claim 63, wherein measuring comprises continuously measuring the first and second analytes in real-time.

68. A system comprising:
an analyte measurement system configured to measure a first analyte and a second analyte of a patient, the analyte measurement system comprising an analyte sensor;

a processor in communication with the analyte measurement system, wherein the processor is coupled to a memory storing instructions that when executed cause the processor to:

- retrieve sensor data of first and second analyte levels, and
- detect at least one condition associated with the sensor data; and

an insulin delivery system in communication with the processor, wherein the processor is configured to cause the insulin delivery system to deliver insulin based on the first and second analyte levels.

69. The system of claim 68, wherein the first analyte comprises glucose and the second analyte comprises ketone.

70. The system of claim 69, wherein an insulin dose is calculated based on the glucose level, and the calculated insulin dose is further adjusted based on the ketone level.

71. The system of claim 69, wherein an insulin sensitivity and/or a carbohydrate ratio are adjusted based on the glucose and ketone levels.

72. The system of claim 68, further comprising a display configured to display one or more first trend arrows of the first analyte and one or more second trend arrows of the second analyte.

73. The system of claim 72, wherein the one or more first trend arrows and the one or more second trend arrows comprise the same number of trend arrows.

74. The system of claim 72, wherein the one or more first trend arrows and the one or more second trend arrows comprise a different number of trend arrows.

75. The system of claim 72, wherein the one or more first trend arrows and the one or more second trend arrows display the same rate of change unit of the first and second analytes.

76. The system of claim 75, wherein the rate of change unit is mmol/L/min.

77. The system of claim 72, wherein the one or more first trend arrows and the one or more second trend arrows display different rate of change units of the first and second analytes.

78. The system of claim 77, wherein the one or more first trend arrows comprises a flat arrow to indicate a different rate of change unit for the one or more first trend arrows than for the one or more second trend arrows.

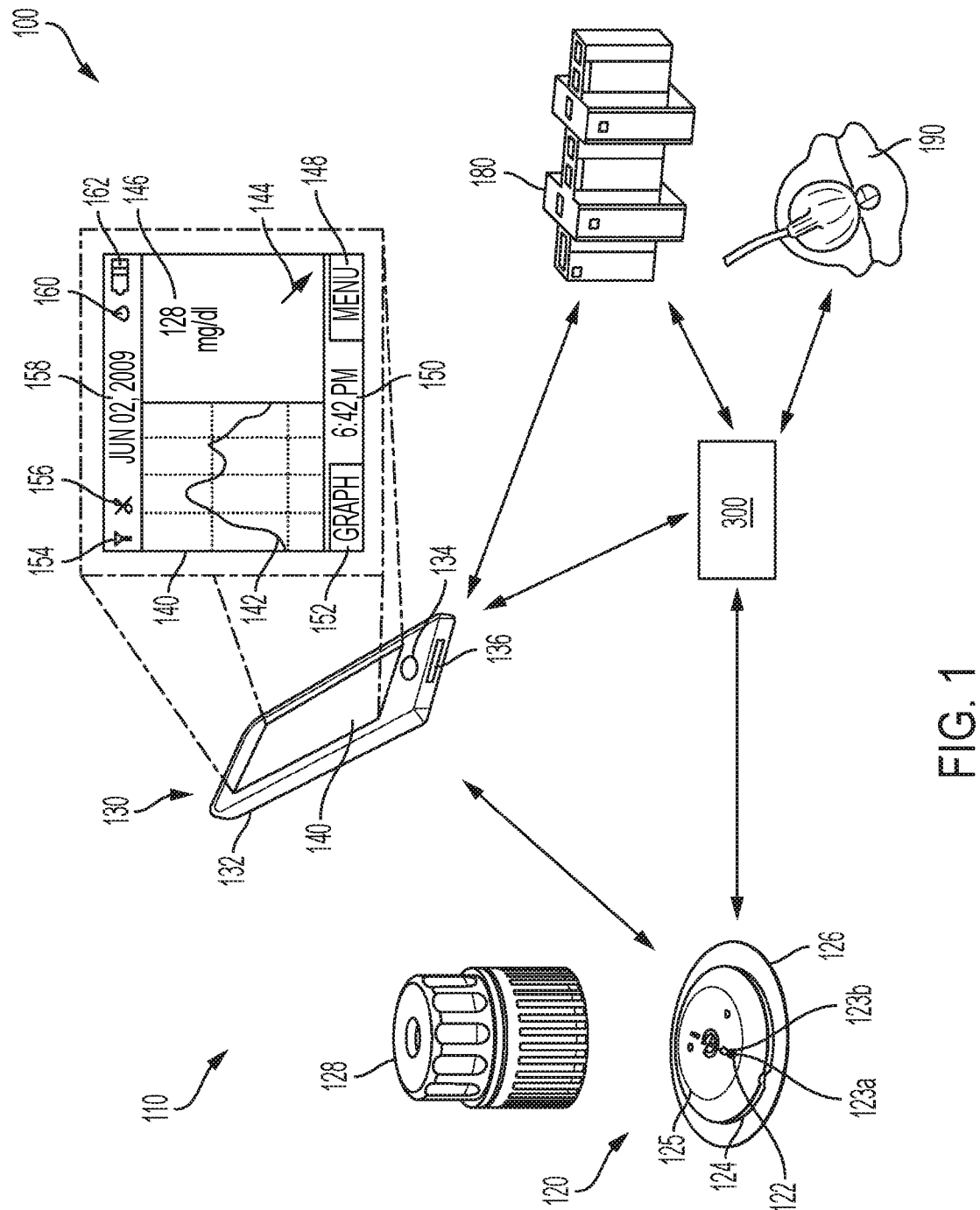


FIG. 1

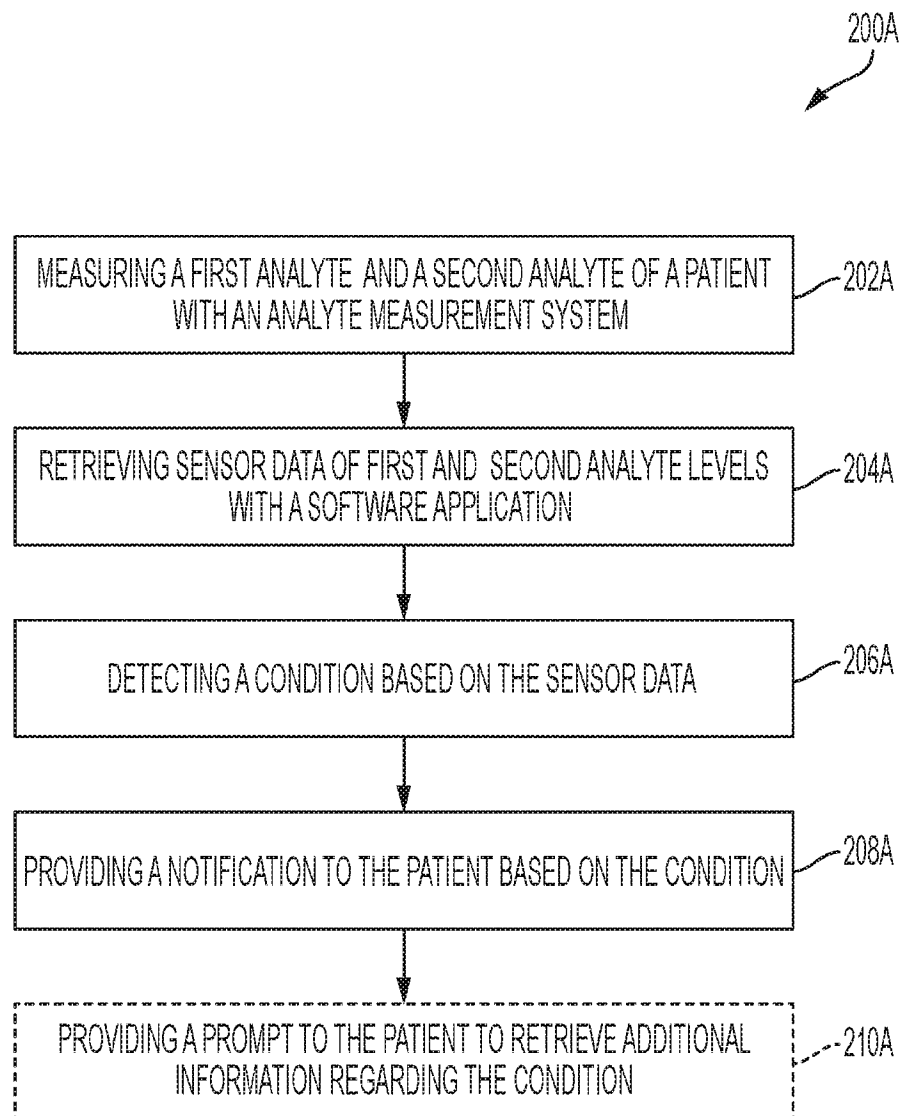


FIG. 2A

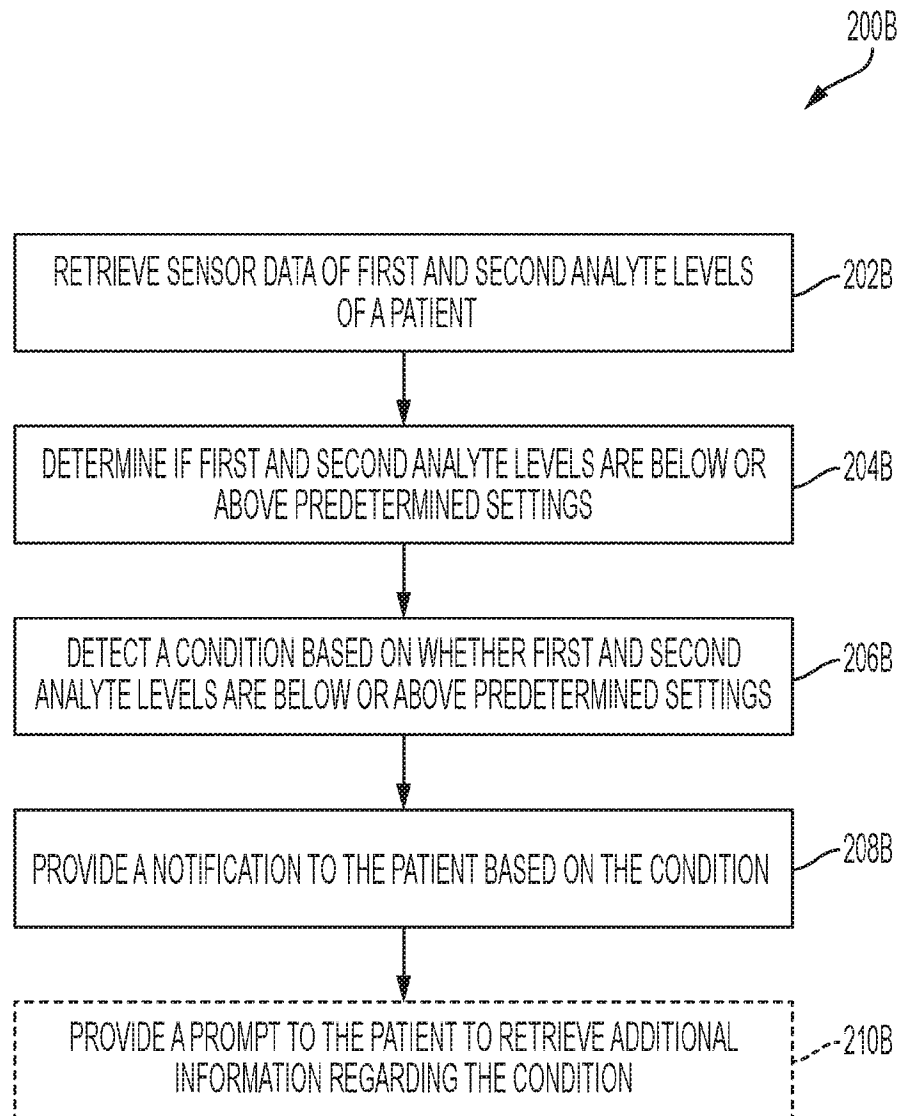


FIG. 2B

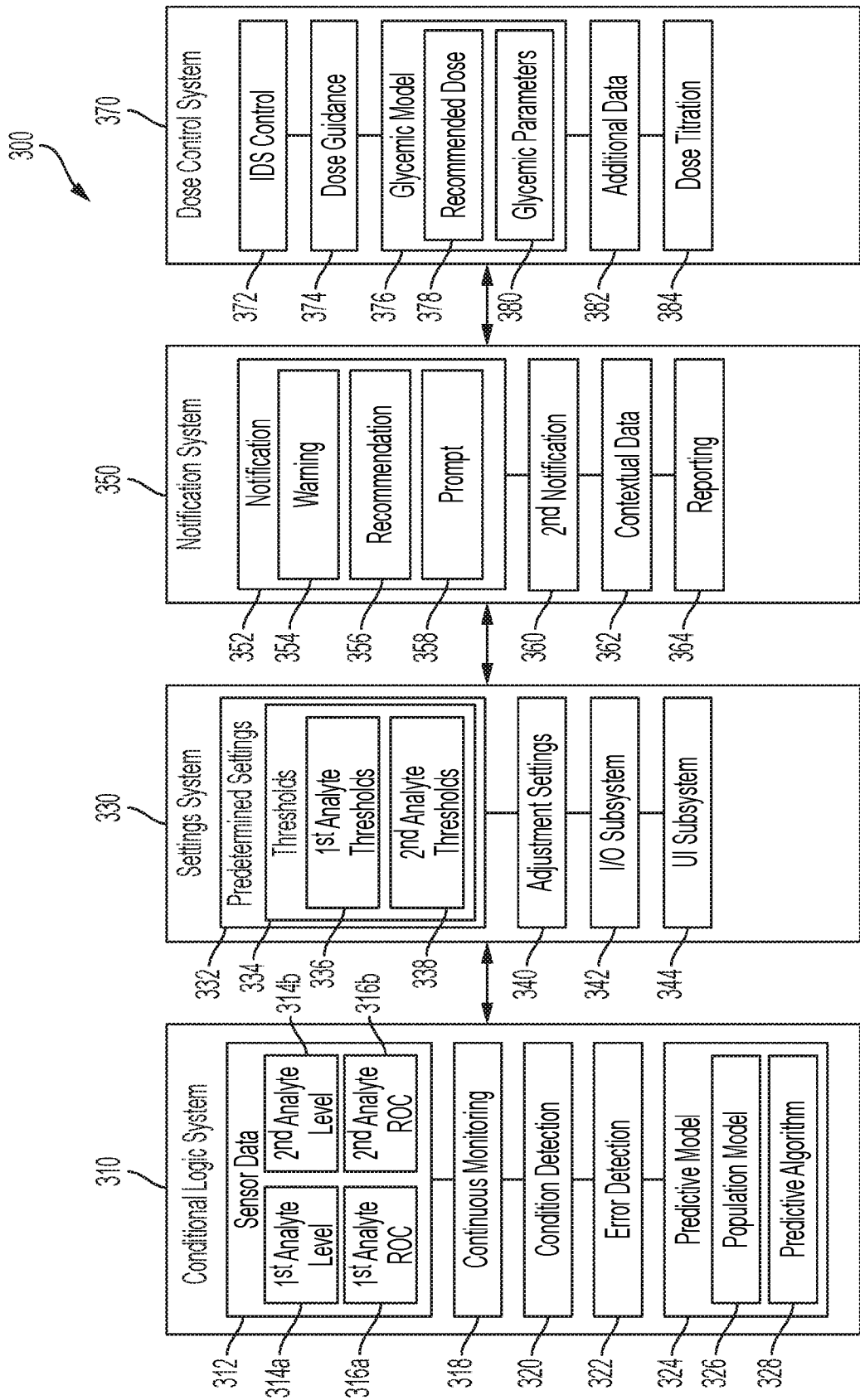


FIG. 3

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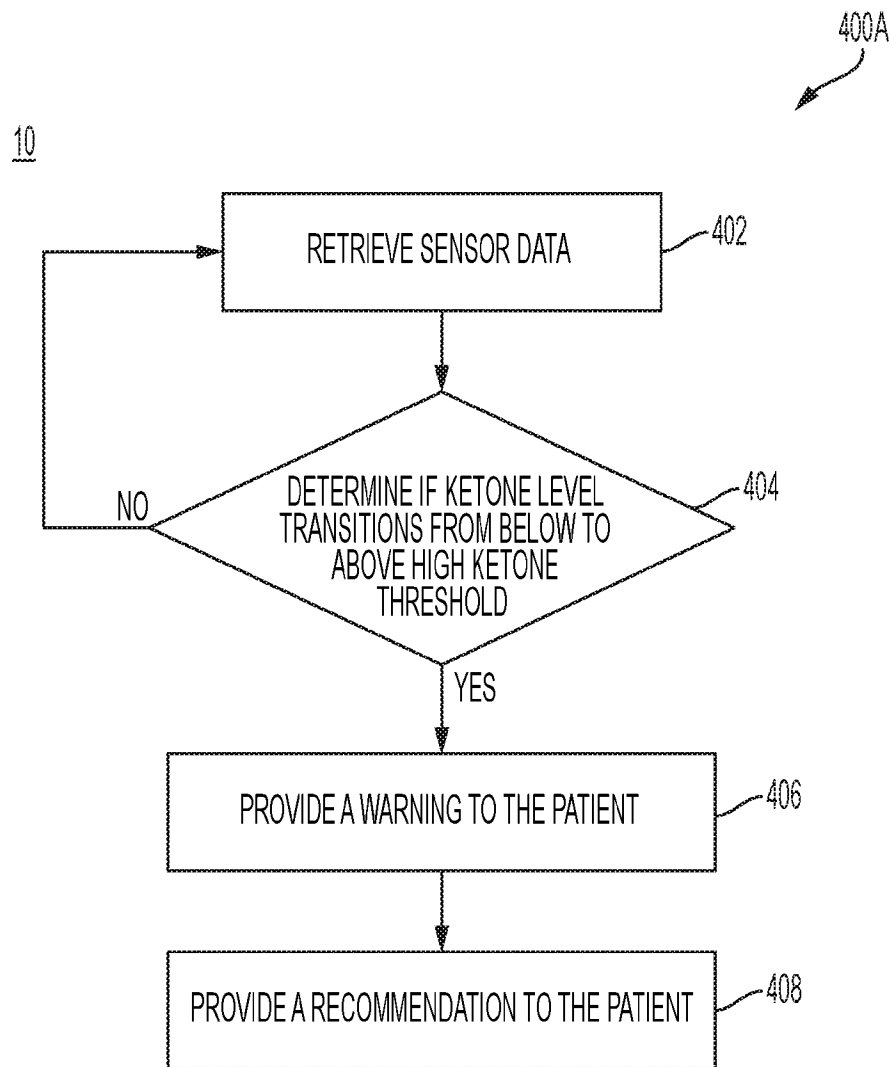


FIG. 4A

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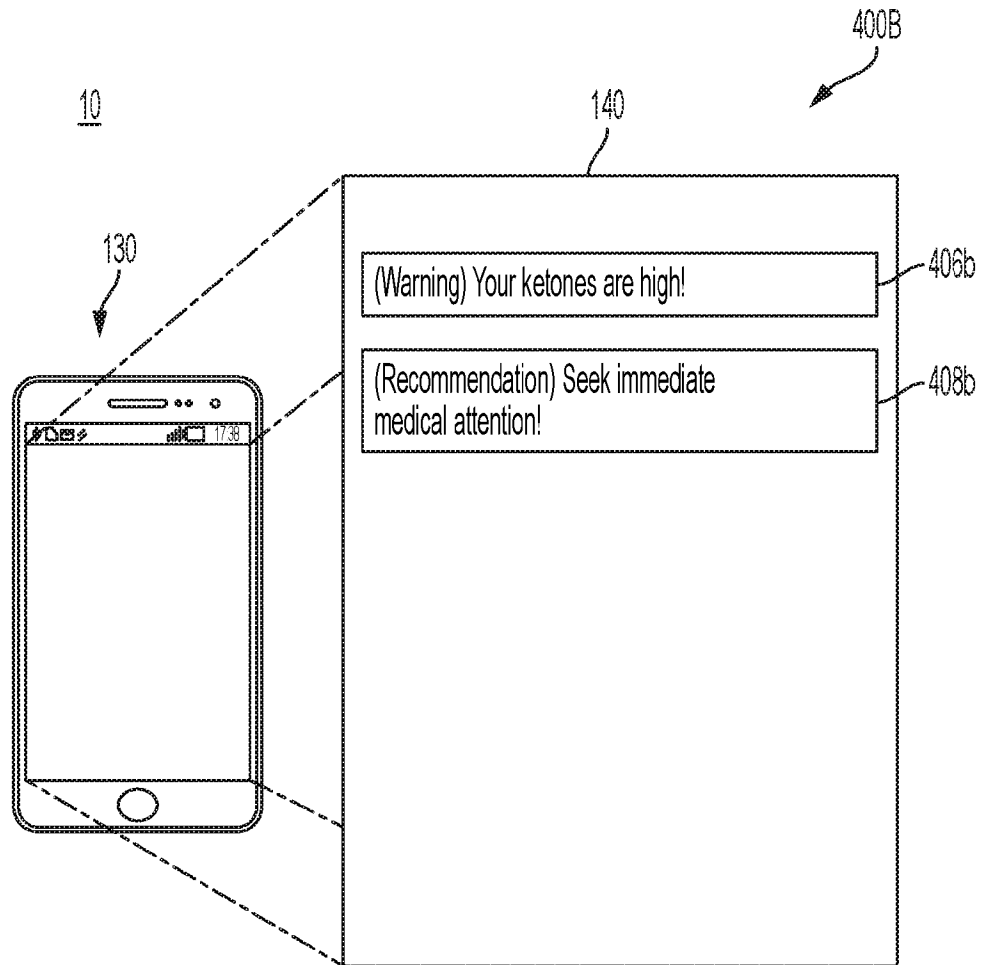


FIG. 4B

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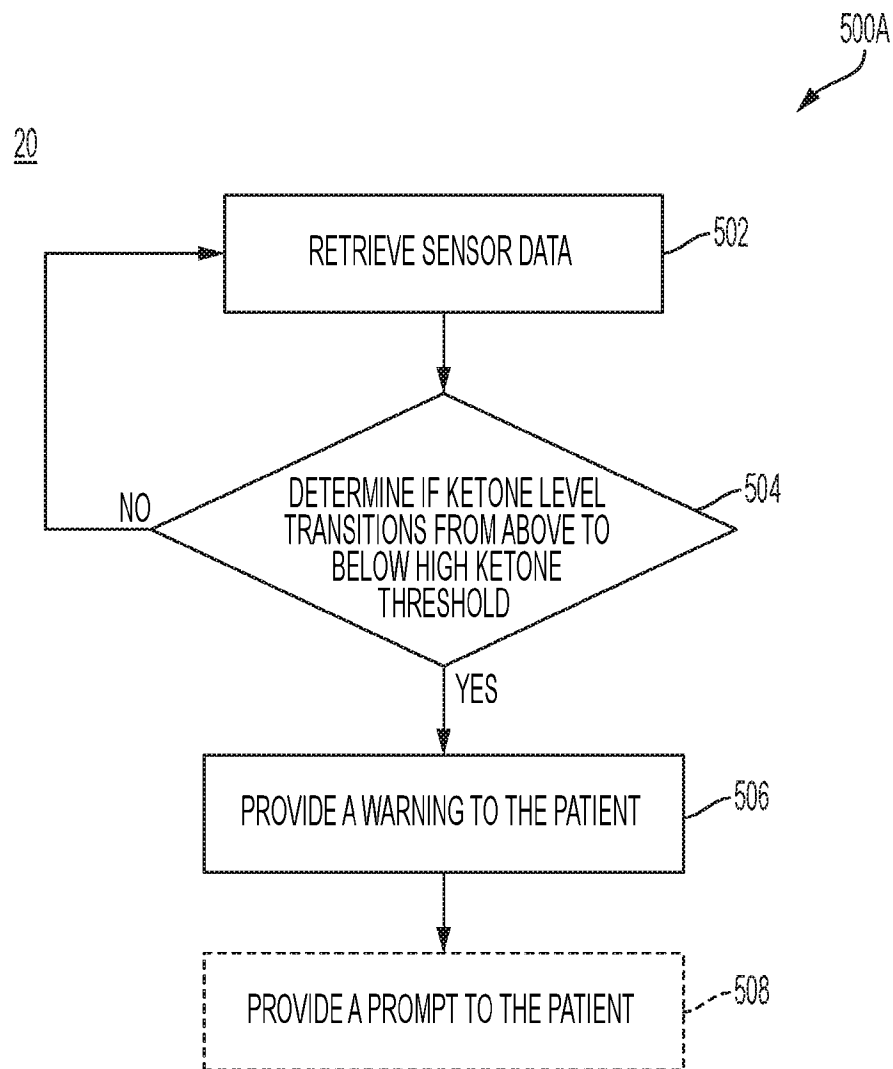


FIG. 5A

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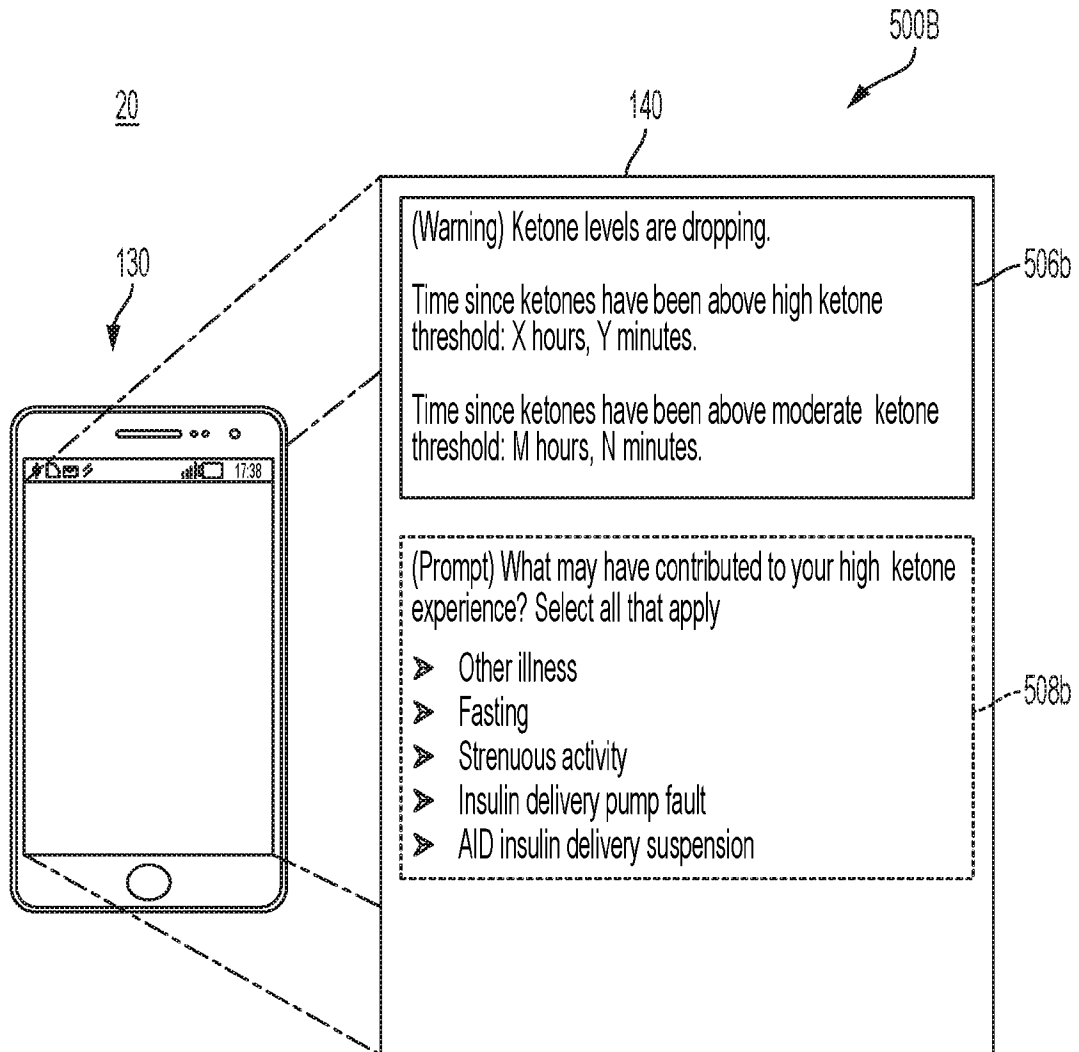


FIG. 5B

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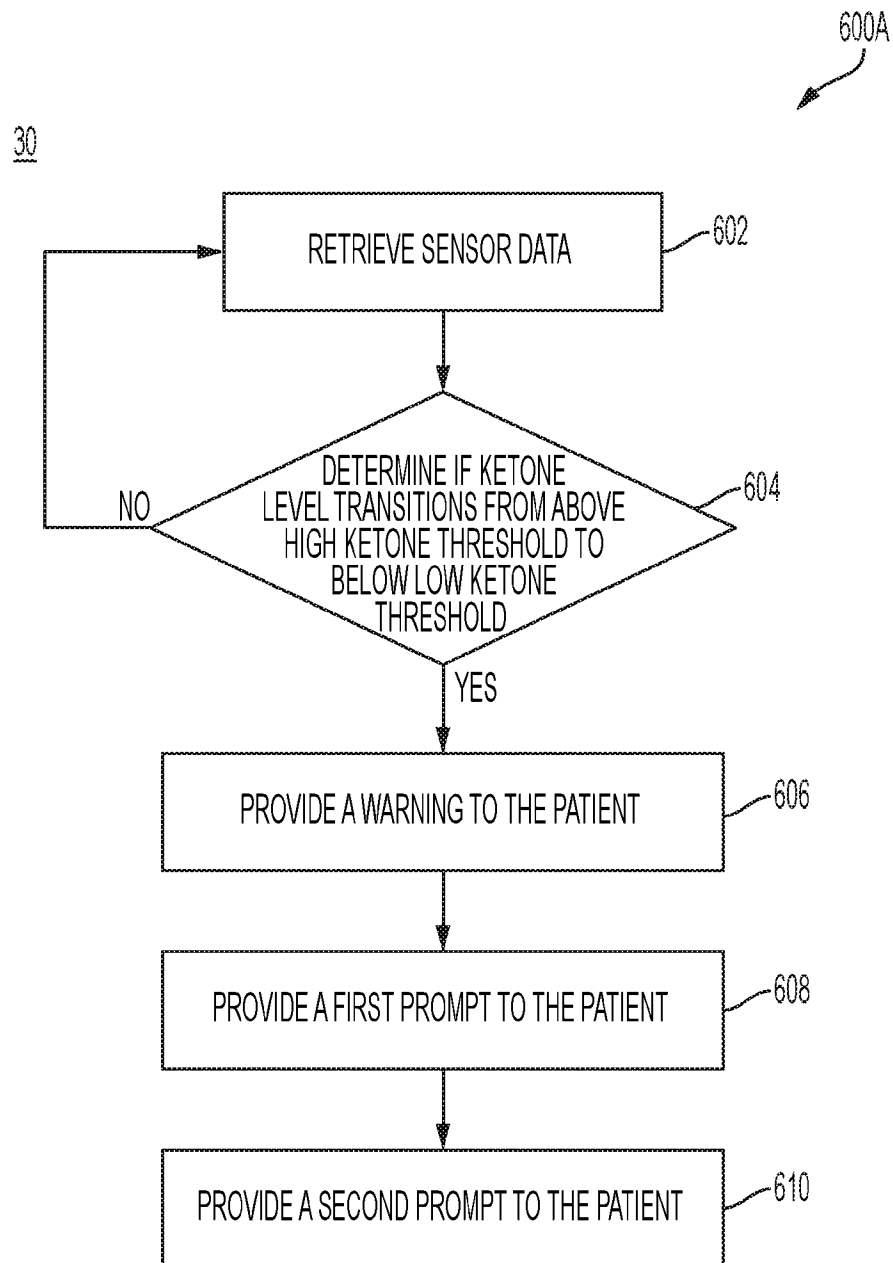


FIG. 6A

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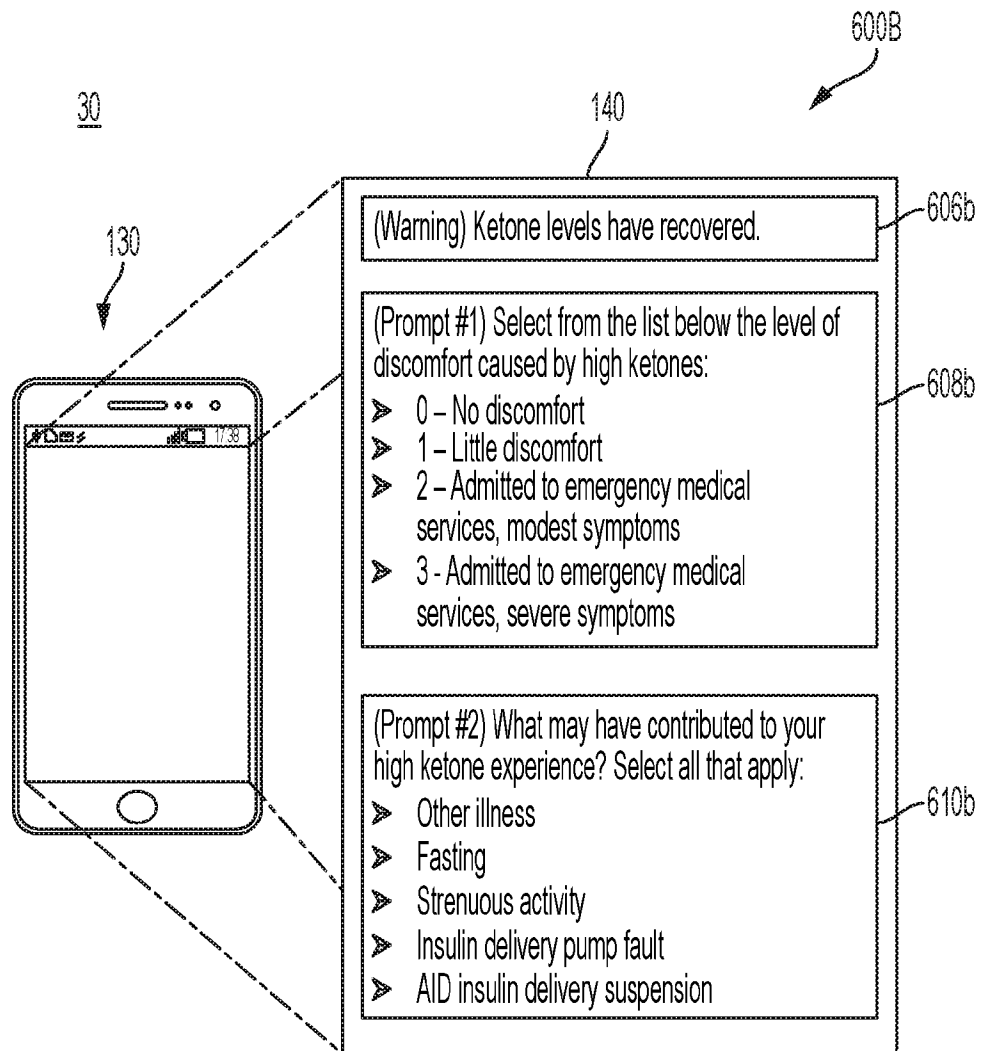


FIG. 6B

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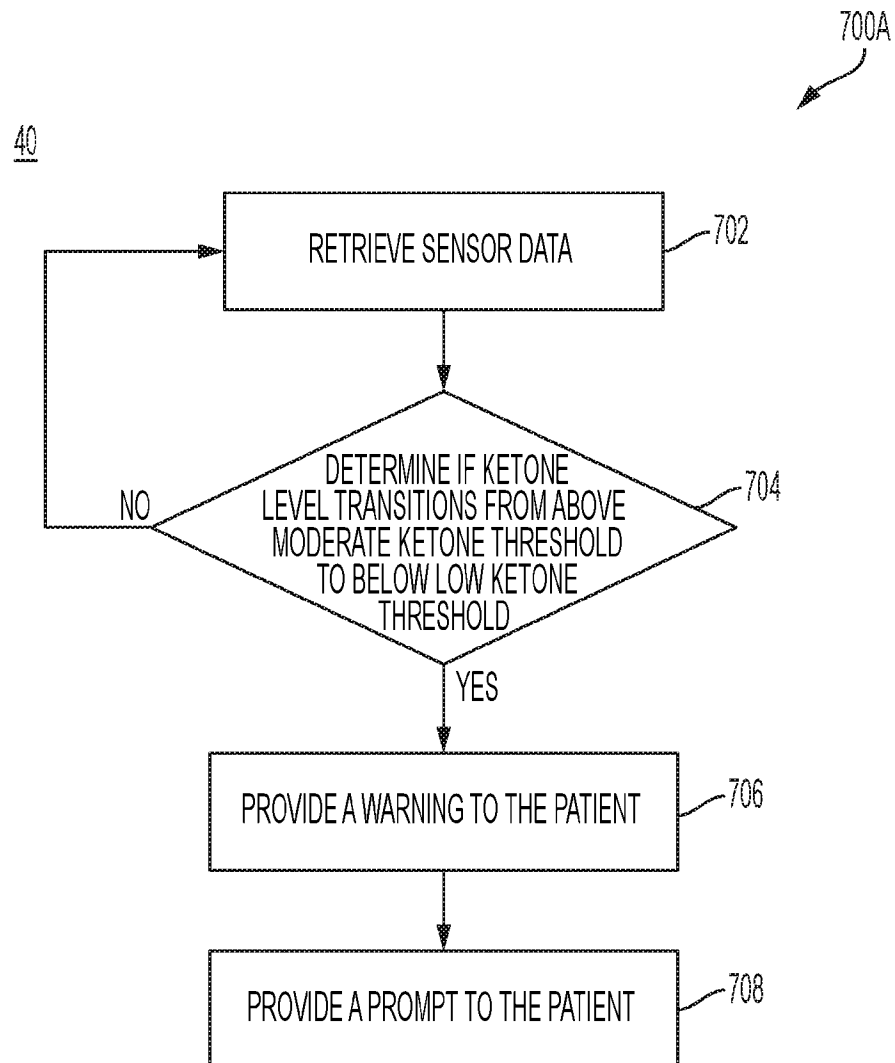


FIG. 7A

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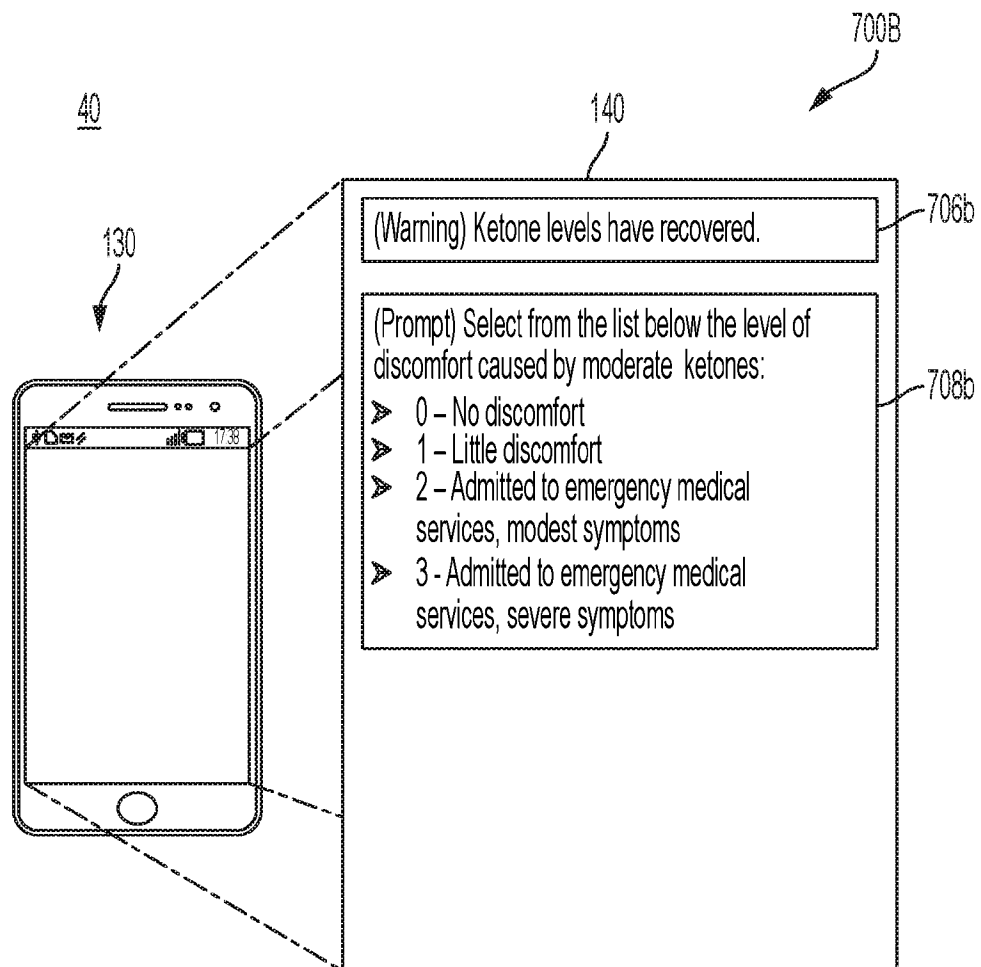


FIG. 7B

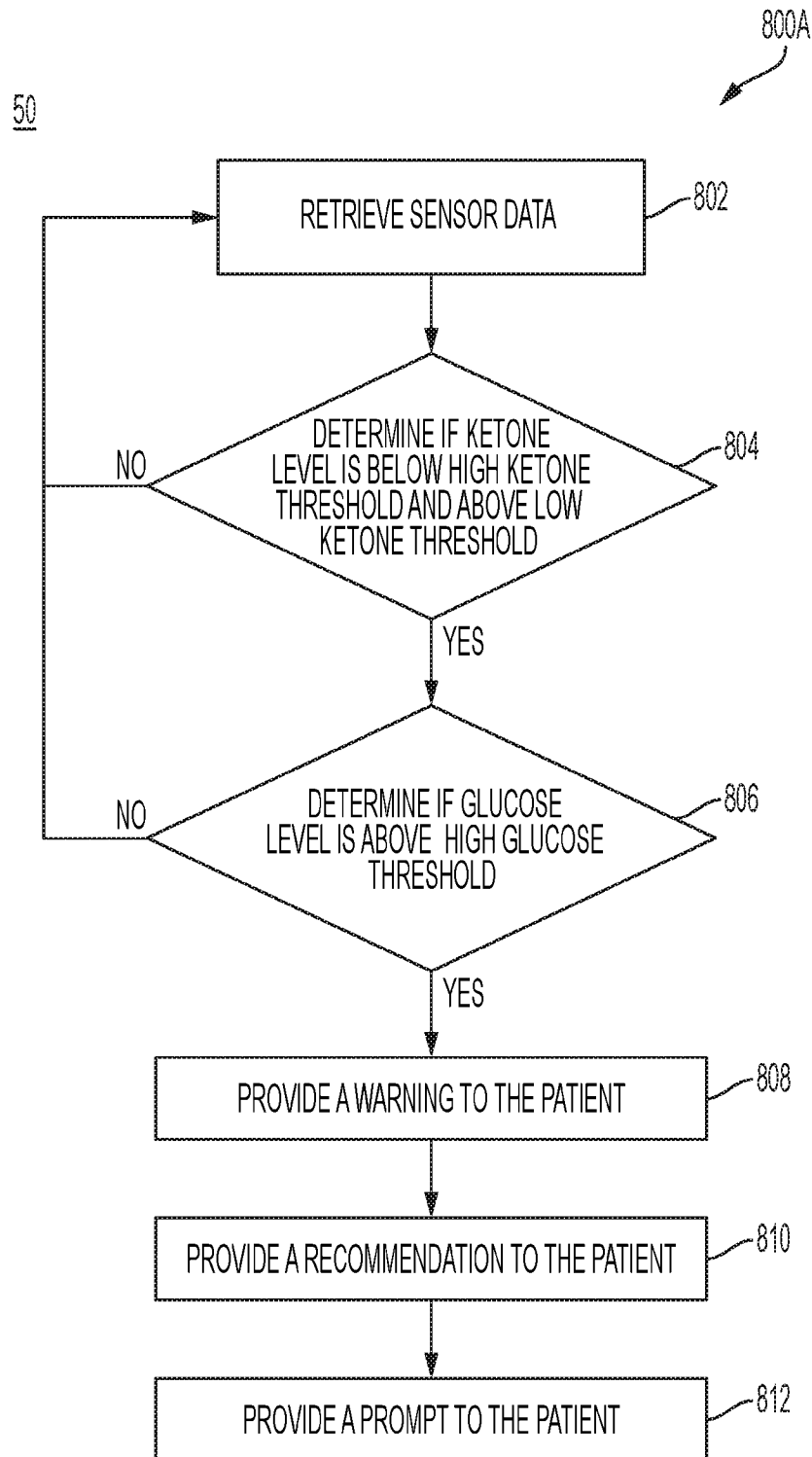


FIG. 8A

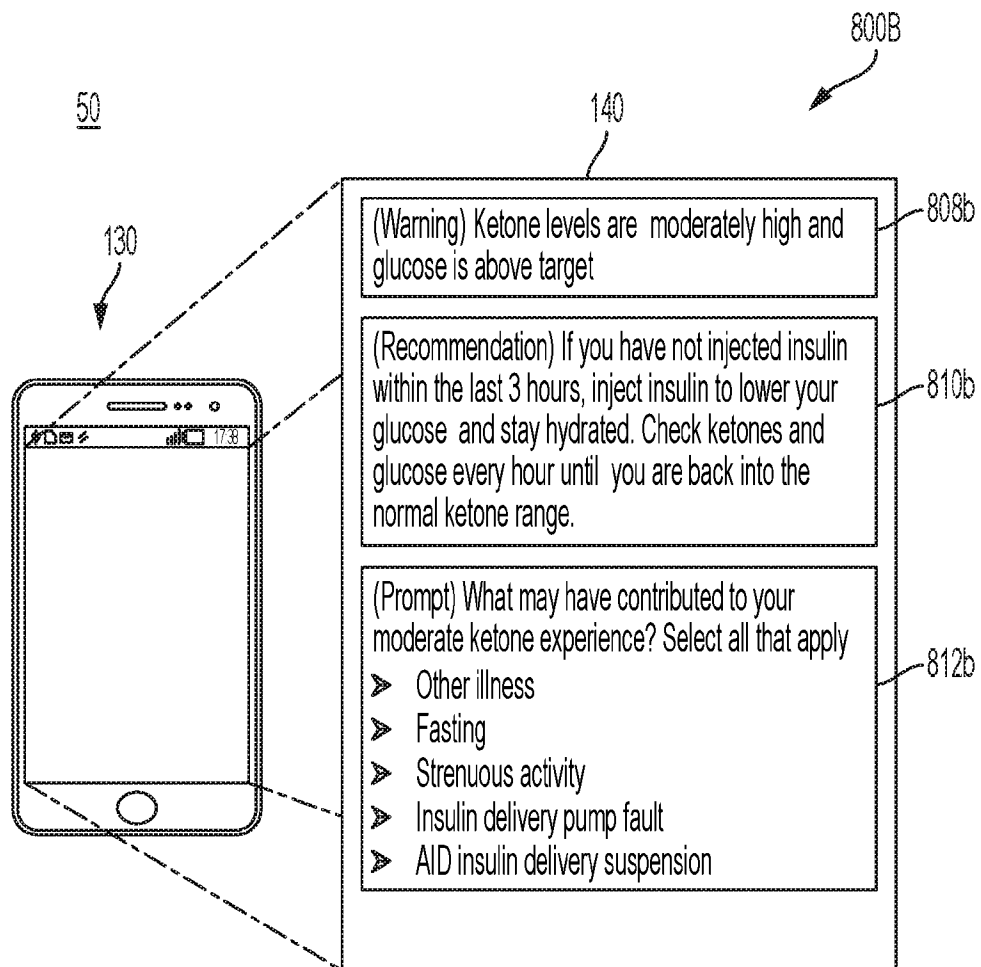


FIG. 8B

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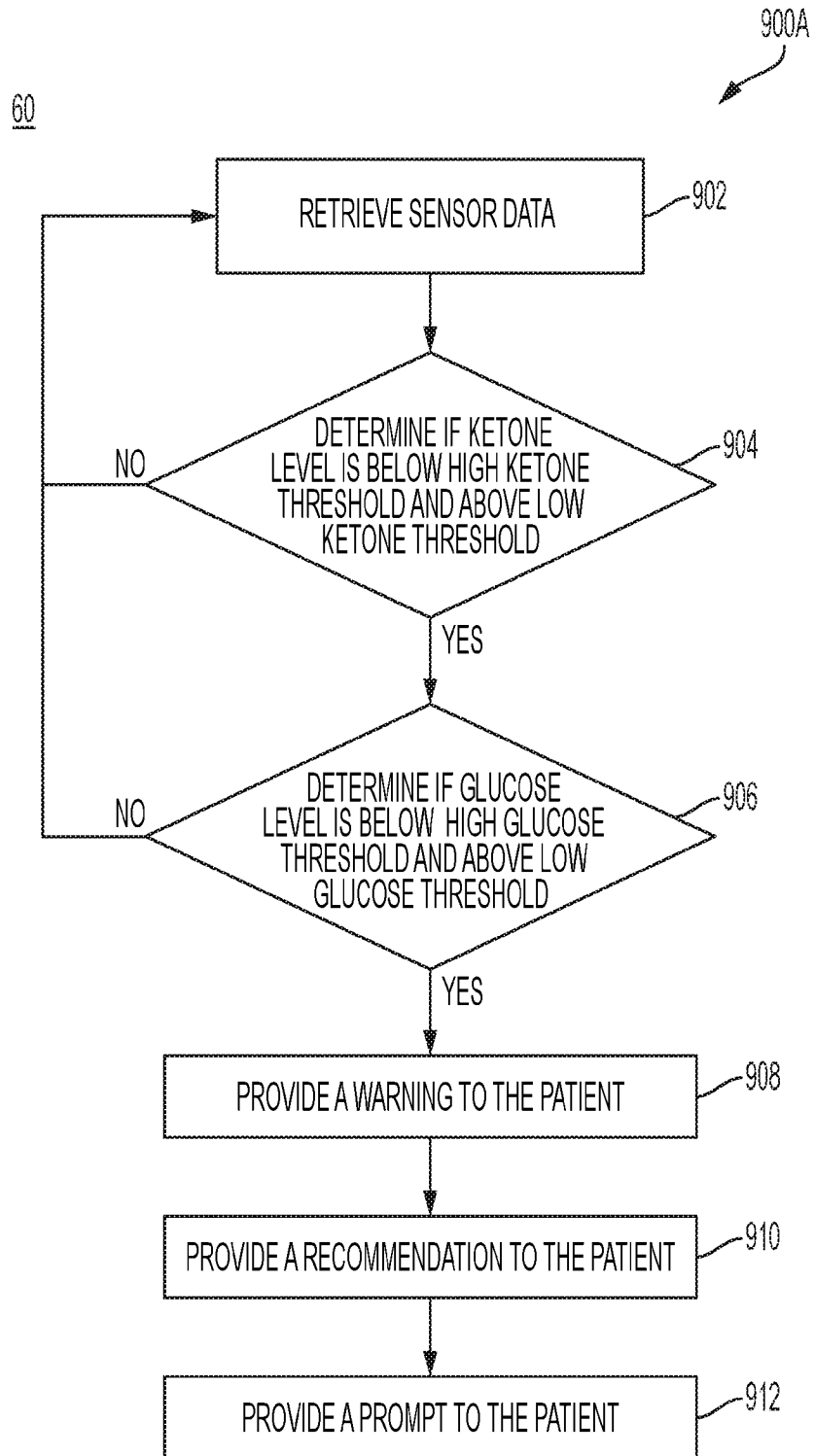


FIG. 9A

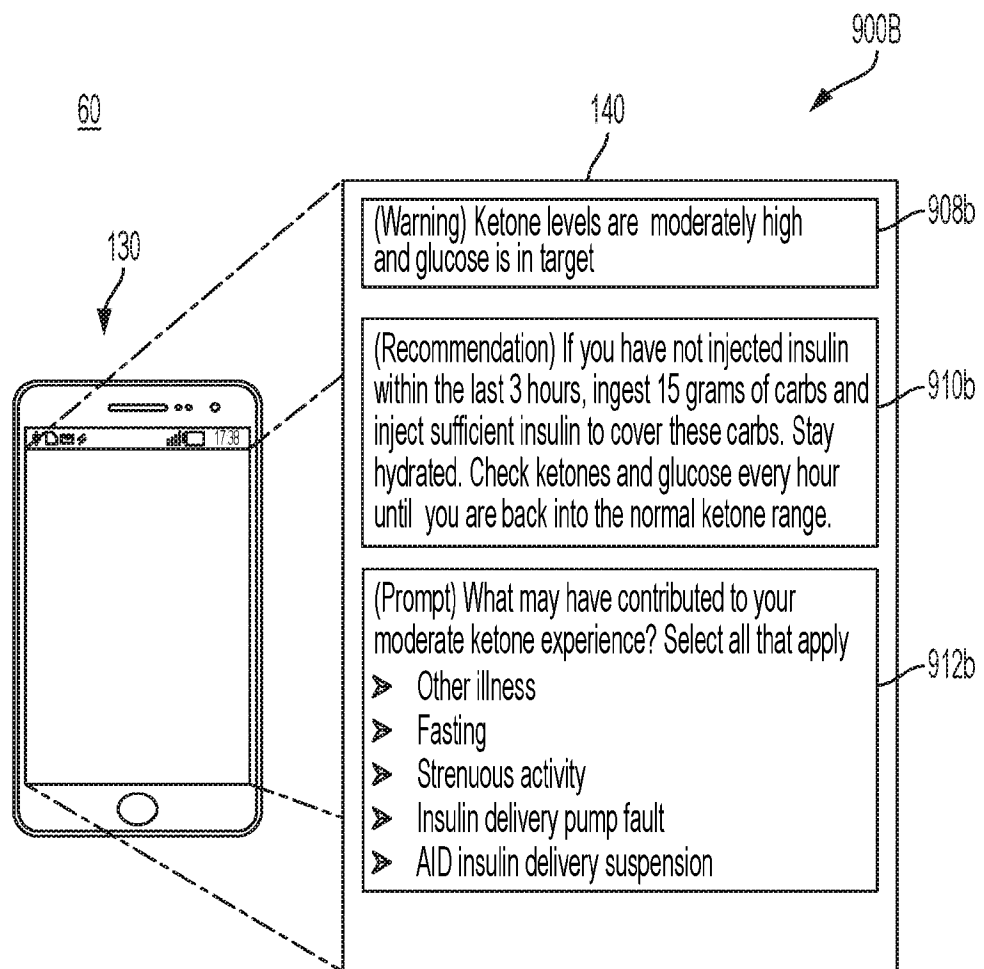


FIG. 9B

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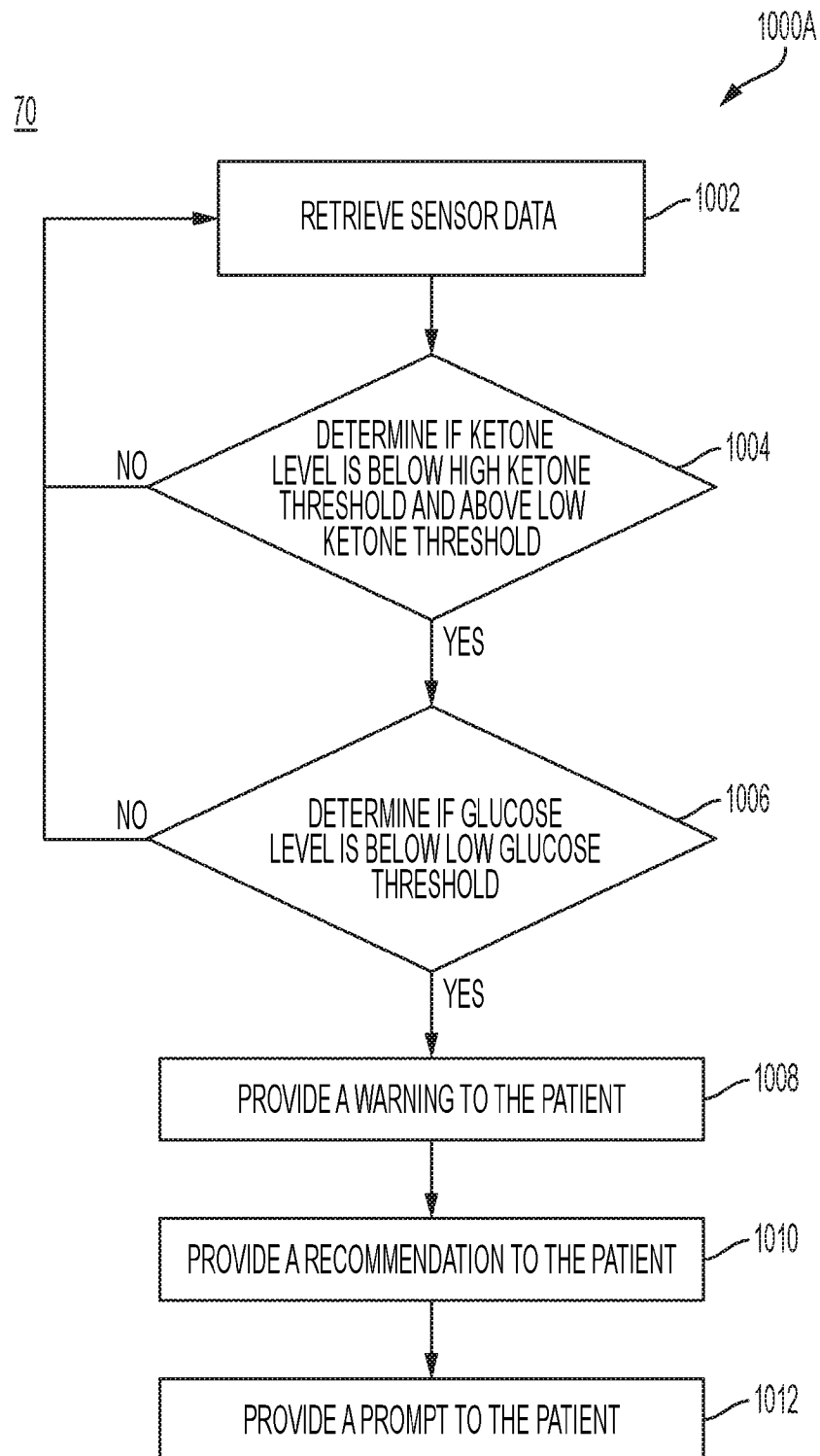


FIG. 10A

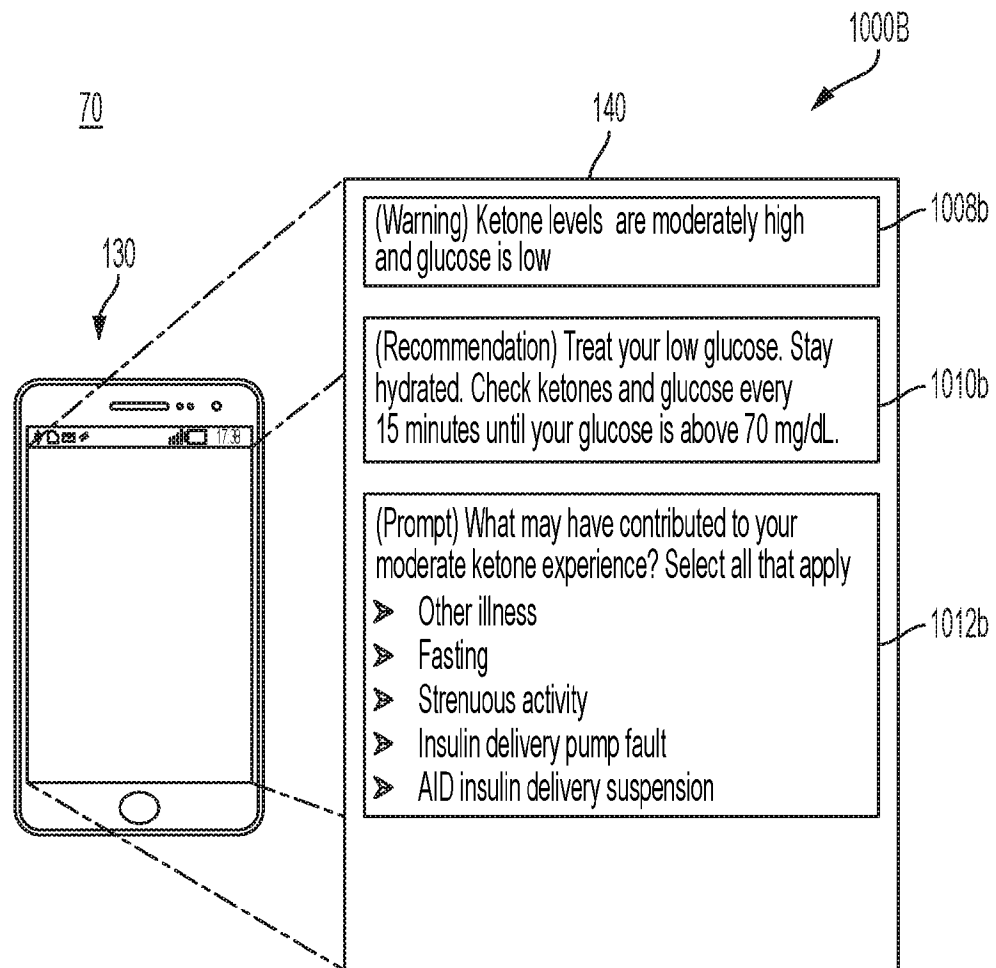


FIG. 10B

1100

	Low Glucose	Normal Glucose	High Glucose
Moderate Ketone	5U Insulin CR= 1:5 (U:g) Calculation: Take 5U; Ingest 5/CR + 15 grams (15 g to cover low glucose)	5U Insulin CR = 1:5 (U:g) Calculation: Take 5U; Ingest 5/CR grams	5U Insulin IS =1:4 (Units:mg/dL) Calculation: Take greater of 5U or IS*glucose
High Ketones	10U Insulin CR = 1:5 (U:g) Calculation: Take 10U; Ingest 5/CR + 15 grams (15 g to cover low glucose)	10U Insulin CR = 1:5 (U:g) Calculation: Take 10U; Ingest 5/CR grams	10U Insulin IS =1:4 (Units:mg/dL) Calculation: Take greater of 10U or IS*glucose

FIG. 11

1200
↙

Basal = f(Ketones) (units per day)

IS = f(Ketones) (mg/dL per unit)

CR = f(Ketones) (grams per unit)

If ketones < 1.0 mmol/L

Then IS = 4 mg/dL/Unit (or in common notation, 1:4)

If ketones ≥ 1.0 AND < 3.0 mmol/L,

Then IS = $4 + \{(\text{ketone} - 1)/2\} * 4$ mmol/L

Otherwise ketones = 8 mmol/L

FIG. 12

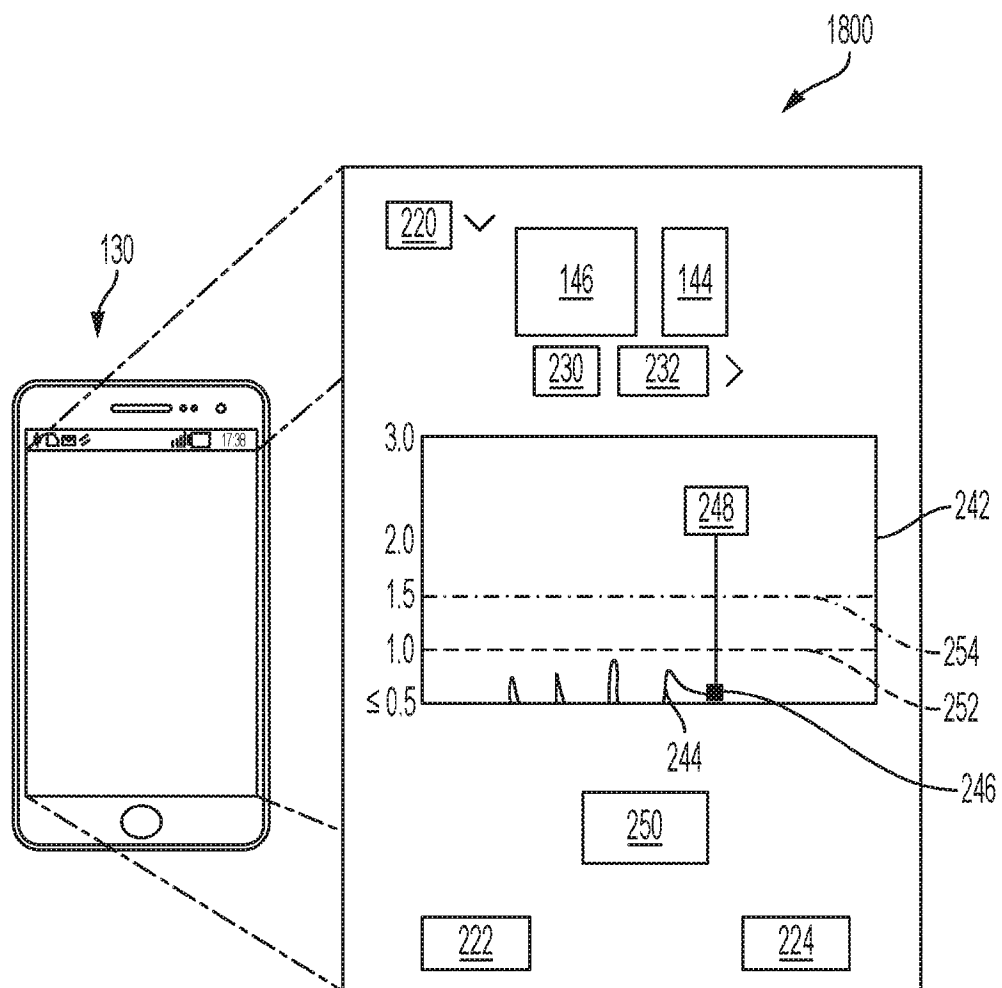


FIG. 13