OCCLUSION DETECTION

TECHNICAL FIELD

This disclosure relates generally to medical devices. More particularly, this disclosure relates to systems for, and methods of, occlusion detection.

BACKGROUND

In the medical arts, the term "occlusion" typically refers to the blocking or restriction of a normally open passage. In some instances, an occlusion is desired such as when a catheter is pinched off or temporarily collapsed into a closed state intentionally by a practitioner during a medical procedure. In other instances, an unintended occlusion could result in a potentially dangerous situation. For example, in the field of medication delivery devices and systems including so-called "syringe pumps", typically a pre-filled medication syringe is mechanically driven under microprocessor control to deliver a prescribed dose of medication at a controlled rate to a patient through an infusion line fluidly connected to the syringe. Syringe pumps typically include a motor that rotates a leadscrew. The leadscrew in turn activates a plunger driver which forwardly pushes a plunger within a barrel of the syringe. Pushing the plunger forward thus forces the dose of medication outwardly from the syringe, into the infusion line, and to the patient intravenously. Examples of syringe pumps are disclosed in, for example, U.S. Pat. No. 4,978,335 titled "Infusion Pump with Bar Code Input to Computer" and U.S. Pat. Applic. Pub. No. 2005/0096593 titled "Syringe Pump Rapid Occlusion Detection System". As used throughout this disclosure, the term "syringe pump" is intended to generally pertain to any device which acts on a syringe to controllably force fluid outwardly therefrom.

In such devices, an occlusion might occur when the intended and commanded forward progression of the plunger longitudinally through the syringe barrel is blocked or otherwise impeded, as when for example the infusion line tubing is kinked or otherwise structurally blocked to some degree. If the occlusion is not noticed, the patient likely would not receive the prescribed medication leading to potentially serious consequences.

Attempts to sense or detect occlusions in medical devices such as syringe pumps have therefore been made. For example, some syringe pumps detect occlusions by use of a pressure sensor that senses a force exerted by the aforementioned syringe thumb-press on the plunger driver. When the force experienced by the pressure sensor exceeds a predetermined threshold force, a processor connected to the pressure sensor generates a signal indicating that an occlusion has possibly occurred or is possibly occurring. Since syringe pumps are typically capable of

accommodating a range of syringe diameters or sizes (e.g., 10 ml through 50 ml capacities) the plunger driver and pressure sensor may likely experience varying occlusion force vectors depending upon which particular size of syringe is being used in the syringe pump, leading to varying accuracy and responsiveness overall in the pump's occlusion sensing system. Since the occlusion force (F) is a function of pressure (P) exerted on the sensor over an area (A) experiencing the pressure (i.e., P = F /A) as the area decreases the pressure increases. Typically, therefore, smaller diameter syringes yield smaller sensed forces for given pressures upon occurrences of occlusions. Thus, known occlusion detection systems and methods have not been entirely satisfactory in sensing and signaling occlusions for relatively smaller diameter syringes.

Consequently, it would be useful and advantageous to provide systems for, and methods of, occlusion detection, particularly when using syringes of relatively small diameters in syringe pumps.

SUMMARY

This disclosure describes novel and inventive systems for, and methods of, occlusion detection.

In one aspect, a system for occlusion detection could include a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes a plunger driver. A bendable element could be integrally formed with the plunger driver, and a force sensor could also be integrally formed with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the bendable element, thereby deflecting the bendable element into contact with the force sensor to thereby generate a signal indicating the occurrence of the occlusion.

In another aspect, a system of occlusion detection could include a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes a plunger driver. A pivotable element could be connected to the plunger driver by a link. A force sensor could be integrally formed with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the pivotable element, thereby deflecting the pivotable element about the link into contact with the force sensor to thereby generate a signal indicating the occurrence of the occlusion.

In another aspect, a system of occlusion detection could include a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes a plunger driver. A pivotable sliding element having a spring-loaded slot could be connected to the plunger driver by a link residing within the spring-loaded slot. A force sensor could be integrally formed with the plunger driver. Upon occurrence of an occlusion, the

plunger would exert a force backwardly against the pivotable sliding element, thereby deflecting the pivotable sliding element about the link into contact with the force sensor to thereby generate a signal indicating the occurrence of the occlusion.

In another aspect, a system of occlusion detection could include a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes a plunger driver. A substantially unitary, combination component of a bendable element with a force sensor could be integrally formed with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the combination component, thereby deflecting the combination component such that a signal is thereby generated to indicate the occurrence of the occlusion.

In another aspect, a system for occlusion detection could include a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes a plunger driver. A bendable element could be integrally formed with the plunger driver, and a force sensor could also be integrally formed with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the bendable element, thereby deflecting the bendable element into contact with the force sensor to thereby generate a signal indicating the occurrence of the occlusion. The system for occlusion detection could be characterised in that forces exerted backwardly against the bendable element resulting from occurrences of occlusions, acting on the force sensor, increase in magnitude as syringe sizes decrease due to correspondingly greater moment arms on the bendable element.

In another aspect, a system of occlusion detection could include a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes a plunger driver. A pivotable element could be connected to the plunger driver by a link. A force sensor could be integrally formed with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the pivotable element, thereby deflecting the pivotable element about the link into contact with the force sensor to thereby generate a signal indicating the occurrence of the occlusion. The system of occlusion detection could be characterised in that forces exerted backwardly against the pivotable element resulting from occurrences of occlusions, acting on the force sensor, increase in magnitude as syringe sizes decrease due to correspondingly greater moment arms on the pivotable element.

In another aspect, a system of occlusion detection could include a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes a plunger driver. A pivotable sliding element having a spring-loaded slot could be connected to the plunger driver by a link residing within the spring-loaded slot. A force sensor

could be integrally formed with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the pivotable sliding element, thereby deflecting the pivotable sliding element about the link into contact with the force sensor to thereby generate a signal indicating the occurrence of the occlusion. The system of occlusion detection could be characterised in that forces exerted backwardly against the pivotable sliding element resulting from occurrences of occlusions, acting on the force sensor, increase in magnitude as syringe sizes decrease due to correspondingly greater moment arms on the pivotable sliding element.

In another aspect, a system of occlusion detection could include a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes a plunger driver. A substantially unitary, combination component of a bendable element with a force sensor could be integrally formed with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the combination component, thereby deflecting the combination component such that a signal is thereby generated to indicate the occurrence of the occlusion. The system for occlusion detection could be characterised in that forces exerted backwardly against the combination component resulting from occurrences of occlusions, acting on the combination component, increase in magnitude as syringe sizes decrease due to correspondingly greater moment arms on the combination component.

In another aspect, a method of occlusion detection could include providing a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes (i) a plunger driver, (ii) an element with the plunger driver, the element being selected from a group consisting of a bendable element, a pivotable element, and a pivotable sliding element, and (iii) a force sensor integrally formed with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the element, thereby deflecting the element into contact with the force sensor to thereby generate a signal indicating the occurrence of the occlusion. The medication could be administered to a patient by way of the syringe pump, and the signal generated by the sensor could be sent to medical staff upon the occurrence of the occlusion.

In another aspect, a method of occlusion detection could include providing a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and the syringe pump includes (i) a plunger driver and (ii) a substantially unitary, combination component of a bendable element with a force sensor, with the plunger driver. Upon occurrence of an occlusion, the plunger would exert a force backwardly against the combination component, thereby deflecting the combination component such that a signal is thereby generated to indicate the occurrence of the occlusion. The medication could be administered to a patient by way of

the syringe pump, and the signal generated by the sensor could be sent to medical staff upon the occurrence of the occlusion.

BRIEF DESCRIPTION OF THE DRAWINGS

Systems for, and methods of, occlusion detection are illustrated by way of example and not limitation in the figures of the accompanying drawings in which:

Figure 1 is a schematic diagram of a system for occlusion detection, in use with a relatively large medication syringe.

Figure 1A is schematic diagram of the system shown in Figure 1, in use with a relatively small medication syringe.

Figure 2 is a schematic diagram of an alternative embodiment of a system for occlusion detection, in use with a relatively large medication syringe.

Figure 2A is schematic diagram of the system shown in Figure 2, in use with a relatively small medication syringe.

Figure 3 is a schematic diagram of an alternative embodiment of a system for occlusion detection, in use with a relatively large medication syringe.

Figure 3A is schematic diagram of the system shown in Figure 3, in use with a relatively small medication syringe.

Figure 4 is a schematic block diagram of a method for occlusion detection.

DETAILED DESCRIPTION

Occlusion detection systems and methods, that are described in greater detail by way of examples herein, make novel and inventive use of decreasing syringe diameters or sizes in syringe pumps to compensate for the aforementioned relatively smaller sensed occlusion forces that are otherwise generated by smaller diameter syringes. Such compensation advantageously results in more constant occlusion forces sensed for given pressures across varying ranges of syringe diameters or sizes used in syringe pumps; and better resolution and sensitivity in occlusion detection is achieved for smaller syringes that are used in, for example, neonatal care units when accuracy and precision in medication delivery are of paramount importance.

Generally, the aforementioned compensation is achieved by way of an element with a plunger driver of a syringe pump that is mechanically linked to a plunger of a syringe in the pump. The element is capable of bending, pivoting, or rotating about a point, upon displacement by an occlusion force acting backwardly on it as transmitted by the plunger. The element then bends, pivots, or rotates about the point, and thereby applies a force to a force sensor. The force

sensor then outputs a signal indicative of an occurrence of an occlusion. As syringe diameter decreases, such as when, e.g., a 30 ml syringe is replaced in the pump by a 20 ml syringe, an occlusion force from the plunger of the smaller syringe acts on the element more distantly from the point about which the element bends, pivots, or rotates; and thus a relatively larger moment arm results with a correspondingly higher force experienced by the force sensor.

Referring now to Figure 1, therein illustrated generally is an example of an embodiment of a system for occlusion detection 10. System 10 includes a syringe pump 100 for a syringe S having a plunger P. Syringe S is of a size or diameter (N) (e.g., a 30 ml syringe) that contains a medication to be delivered to a patient from pump 100 acting on syringe S by way of a plunger driver 110. Driver 110 includes an integrally formed bendable element 120. A force sensor 130 is also integrally formed with driver 110. As shown in Figure 1, upon occurrence of an occlusion plunger P would exert a force backwardly against bendable element 120, thereby deflecting element 120 (indicated by phantom line F) into contact with force sensor 130 to thereby generate a signal indicating the occurrence of the occlusion. With reference now to Figure 1A, it is to be appreciated and understood that upon occurrence of an occlusion with use of a syringe S of a size, or diameter, (N-) (e.g., a 20 ml syringe) plunger P would exert a force backwardly against bendable element 120, but at a greater distance downwardly along element 120 compared to Figure 1. Thereby, in Figure 1A, element 120 would be deflected (indicated by phantom line F(+)) with a greater moment arm and thus into more forceful contact with force sensor 130, compared to such contact from a relatively shorter moment arm shown in Figure 1 from the larger syringe size (N).

Another embodiment of an example of a system for occlusion detection 20 is illustrated generally in Figure 2. System 20 includes a syringe pump 200 for a syringe S having a plunger P. Syringe S is of a size or diameter (N) (e.g., a 30 ml syringe) that contains a medication to be delivered to a patient from pump 200 acting on syringe S by way of a plunger driver 210. A pivotable element 220 is connected to driver 210 by a link 225 (e.g., a pin through a corresponding hole in element 220). A force sensor 230 is integrally formed with driver 210. As shown in Figure 1, upon occurrence of an occlusion plunger P would exert a force backwardly against pivotable element 220, thereby deflecting element 220 about link 225 (indicated by phantom line F) into contact with force sensor 230 to thereby generate a signal indicating the occurrence of the occlusion. With reference now to Figure 2A, it is to be appreciated and understood that upon occurrence of an occlusion with use of a syringe S of a size or diameter (N-) (e.g., a 20 ml syringe) plunger P would exert a force backwardly against pivotable element 220, but at a greater distance downwardly along element 220 compared to Figure 2. Thereby, in

Figure 2A, element 220 would be deflected (indicated by phantom line F(+)) with a greater moment arm and thus into more forceful contact with force sensor 230, compared to such contact from a relatively shorter moment arm shown in Figure 2 from the larger syringe size (N).

Another embodiment of an example of a system for occlusion detection 30 is illustrated generally in Figure 3. System 30 includes a syringe pump 300 for a syringe S having a plunger P. Syringe S is of a size or diameter (N) (e.g., a 30 ml syringe) that contains a medication to be delivered to a patient from pump 300 acting on syringe S by way of a plunger driver 310. A pivotable sliding element 320 is connected to driver 310 by a link 325 (e.g., a pin in a spring-loaded slot 327 in element 320; details of the spring-loaded slot 327 have been omitted for clarity of the drawing). A force sensor 330 is integrally formed with driver 310. As shown in Figure 3, upon occurrence of an occlusion plunger P would exert a force backwardly against pivotable sliding element 320, thereby deflecting element 320 about link 325 (indicated by phantom line F) into contact with force sensor 330 to thereby generate a signal indicating the occurrence of the occlusion. With reference now to Figure 3A, it is to be appreciated and understood that upon occurrence of an occlusion with use of a syringe S of a size or diameter (N-) (e.g., a 20 ml syringe) plunger P would exert a force backwardly against pivotable sliding element 320, but at a greater distance downwardly along element 320 compared to Figure 3. Thereby, in Figure 3A, element 320 would be deflected (indicated by phantom line F(+)) with a greater moment arm and thus into more forceful contact with force sensor 330, compared to such contact from a relatively shorter moment arm shown in Figure 3 from the larger syringe size (N).

Referring now to Figure 4, therein illustrated generally is an example of a method for occlusion detection 400 in, e.g., a clinical setting having medical staff M. In this example, medical staff M would load a syringe S of a size (N) containing a selected medication for a patient into a syringe pump (e.g., the aforementioned pumps 100, 200, or 300). As described by example above, syringe S would include a plunger P. The syringe pump would include a plunger driver such as, e.g., the aforementioned drivers 110, 210, and 310. An element (e.g., the aforementioned bendable element 120, pivotable element 220, or pivotable sliding element 320) would be included with the plunger driver. A force sensor such as, e.g., the aforementioned sensors 130, 230, or 330, would be integrally formed with the plunger driver. The syringe pump would administer the medication to the patient (typically, e.g., through an intravenous line from the syringe to the patient). Upon occurrence of an occlusion, the plunger would exert a force backwardly against the element, thereby deflecting the element into contact with the force sensor. The force sensor would responsively generate a signal that would be sent to the medical staff alerting them to the occurrence of the occlusion as indicated by symbol 410 in the drawing.

Although not illustrated herein, another embodiment of an example of a system for occlusion detection could utilize a substantially unitary, combination component of a bendable element with a force sensor. I.e., the force sensor would respond to a bending moment by being incorporated with or into the bendable element itself, instead of separate bendable element and force sensor components as shown in, e.g., the various examples of Figures 1, 2, and 3. In embodiments that have a substantially unitary, combination component of a bendable element with a force sensor - instead of separate components - a smaller syringe in the pump would, upon occurrence of an occlusion, apply a force closer to a free end of the combination component which would again, in turn, advantageously result in a greater moment arm and correspondingly higher force sensor output.

Regardless of particular components or modes of action, it is to be appreciated and understood that systems for, and methods of, occlusion detection such as have been described by example or otherwise contemplated herein could detect occlusions to enhance the safety and accuracy of delivery of medication from syringes to patients. As aforementioned, novel and inventive use is made of decreasing syringe diameters or sizes to compensate for the aforementioned otherwise relatively smaller sensed occlusion forces generated by smaller diameter syringes. That is, what heretofore had been a disadvantage in occlusion detection - decreasing syringe diameters or sizes - is now used to technical advantage as aforedescribed, which may, for example, quite advantageously permit faster occlusion detection in small syringes.

It is also to be particularly appreciated and understood that any embodiment of systems for, and methods of, occlusion detection that have been described by example or otherwise contemplated herein could advantageously be used, or function in association, with principles of determining discrete force values. Such discrete force values could, in turn, determine whether relationships between them depart from expected relationships, etc., as disclosed in the aforecited U.S. Pat. Applic. Pub. No. 2005/0096593; and an entirety of that Pub. No. 2005/0096593 is incorporated herein by reference thereto.

While systems for, and methods of, occlusion detection have been particularly shown and described with reference to the accompanying figures and specification, it should be understood however that other modifications thereto are of course possible; and all of them are intended to be within the true spirit and scope of novel and inventive systems and methods described herein. Thus, configurations and designs of various features could be modified or altered depending upon particular embodiments.

Additionally, dimensioning and scaling of the drawings herein have been chosen to clearly show details of example embodiments. Thus, in some embodiments it is possible that spacing between various features might be visually imperceptible - e.g., the bendable, pivotable, and pivotable sliding elements; and the plunger driver. In any event, dimensioning and scaling could vary significantly across various embodiments of occlusion detection systems and methods.

It should also be appreciated that types, components, dimensions, fabrication processes, and other particulars and parameters of aforedescribed example embodiments may be substituted for others as desired, or that accessories may be added thereto. For example, in one embodiment, the force sensor could comprise a commercially available Honeywell 1865 Pressure Transducer.

It is also to be understood in general that any suitable alternatives may be employed to provide novel and inventive systems for, and methods of, occlusion detection described by example or otherwise contemplated herein. As such, although the bendable elements, force sensors, and combination components (collectively, regardless of particular constructions, "force components") described by example herein have been further described as being "integrally formed" with plunger drivers, it is to be appreciated and understood that this "integrally formed" terminology broadly includes constructions wherein (i) the force components are formed essentially as one with the plunger driver and also wherein (ii) the force components are physically separate from but attached to, connected to, or otherwise contained within, the plunger driver.

Lastly, compositions, sizes, and strengths of various aforementioned components of systems for, and methods of, occlusion detection described by example or otherwise contemplated herein are all a matter of design choice depending upon intended uses thereof.

Accordingly, these and other various changes or modifications in form and detail may also be made, without departing from the true spirit and scope of systems for, and methods of, occlusion detection that may be defined by the appended claims.

CLAIMS

1. A system for occlusion detection, comprising:

a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and said syringe pump includes a plunger driver;

a bendable element integrally formed with said plunger driver; and

a force sensor integrally formed with said plunger driver, wherein upon occurrence of an occlusion, the plunger exerts a force backwardly against said bendable element, thereby deflecting said bendable element into contact with said force sensor to thereby generate a signal indicating the occurrence of the occlusion.

2. A system for occlusion detection, comprising:

a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and said syringe pump includes a plunger driver;

a pivotable element connected to said plunger driver by a link; and

a force sensor integrally formed with said plunger driver, wherein upon occurrence of an occlusion, the plunger exerts a force backwardly against said pivotable element, thereby deflecting said pivotable element about said link into contact with said force sensor to thereby generate a signal indicating the occurrence of the occlusion.

3. A system for occlusion detection, comprising:

a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and said syringe pump includes a plunger driver;

a pivotable sliding element including a spring-loaded slot, said pivotable sliding element being connected to said plunger driver by a link residing within said spring-loaded slot; and

a force sensor integrally formed with said plunger driver, wherein upon occurrence of an occlusion, the plunger exerts a force backwardly against said pivotable sliding element, thereby deflecting said pivotable sliding element about said link into contact with said force sensor to thereby generate a signal indicating the occurrence of the occlusion.

4. A system for occlusion detection, comprising:

a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and said syringe pump includes a plunger driver; and

a substantially unitary, combination component of a bendable element with a force sensor, being integrally formed with said plunger driver, wherein upon occurrence of an occlusion, the plunger exerts a force backwardly against said combination component, thereby deflecting said combination component such that a signal is thereby generated to indicate the occurrence of the occlusion.

5. The system for occlusion detection of claim 1 characterized in that forces exerted backwardly against said bendable element resulting from occurrences of occlusions, acting on said force sensor, increase in magnitude as syringe sizes decrease due to correspondingly greater moment arms on said bendable element.

6. The system for occlusion detection of claim 2 characterized in that forces exerted backwardly against said pivotable element resulting from occurrences of occlusions, acting on said force sensor, increase in magnitude as syringe sizes decrease due to correspondingly greater moment arms on said pivotable element.

7. The system for occlusion detection of claim 3, characterized in that forces exerted backwardly against said pivotable sliding element resulting from occurrences of occlusions, acting on said force sensor, increase in magnitude as syringe sizes decrease due to correspondingly greater moment arms on said pivotable sliding element.

8. The system for occlusion detection of claim 4, characterized in that forces exerted backwardly against said combination component resulting from occurrences of occlusions, acting on said combination component, increase in magnitude as syringe sizes decrease due to correspondingly greater moment arms on said combination component.

9. A method of occlusion detection, comprising:

providing a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and said syringe pump includes (i) a plunger driver, (ii) an element with said plunger driver, said element being selected from a group consisting of a bendable element, a pivotable element, and a pivotable sliding element, and (iii) a force sensor integrally formed with said plunger driver, wherein upon occurrence of an occlusion, the plunger exerts a force backwardly against said element, thereby deflecting said element into contact with said force sensor to thereby generate a signal indicating the occurrence of the occlusion;

administering the medication to a patient by way of said syringe pump; and

sending said signal generated by said sensor to medical staff, upon an occurrence of an occlusion.

10. A method of occlusion detection, comprising:

providing a syringe pump for a syringe containing a medication, wherein the syringe includes a plunger and said syringe pump includes (i) a plunger driver and (ii) a substantially unitary, combination component of a bendable element with a force sensor, with said plunger driver, wherein upon occurrence of an occlusion, the plunger exerts a force backwardly against said combination component, thereby deflecting said combination component such that a signal is thereby generated to indicate the occurrence of the occlusion;

administering the medication to a patient by way of said syringe pump; and

sending said signal generated by said combination component to medical staff, upon an occurrence of an occlusion.