



(51) International Patent Classification:

A61M 5/142 (2006.01) F04B 43/08 (2006.01)
A61M 5/168 (2006.01)

(21) International Application Number:

PCT/IL2018/050409

(22) International Filing Date:

09 April 2018 (09.04.2018)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/629,038 11 February 2018 (11.02.2018) US

(71) Applicant: AVOSET HEALTH LTD. [IL/IL]; 29 Yad
Haruzim Street, 4250529 Netanya (IL).

(72) Inventors: EITAN, Boaz; 33 Cochav Hayam Street,
4029500 Hofit (IL). SHTOLTZ, Ram; 29/4 Jabotin-
sky Street, 6228705 Tel-Aviv (IL). RASOWSKY, Amir;
Yakir, 4484300 Yakir (IL). PESACH, Gidi; 107 Derech
Habeer Street, 4020000 Kfar Vitkin (IL). OVADIA, Nir;
14 Hatanaim Street, 4247406 Netanya (IL).

(74) Agent: FISHER, Michal et al.; FISHER IP GROUP, PO
BOX 12352, 4673300 Herzliya Pituach (IL).

(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, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,

MG, MK, MN, 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, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, 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, 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).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) Title: FLEX-STROKE INFUSION PUMP

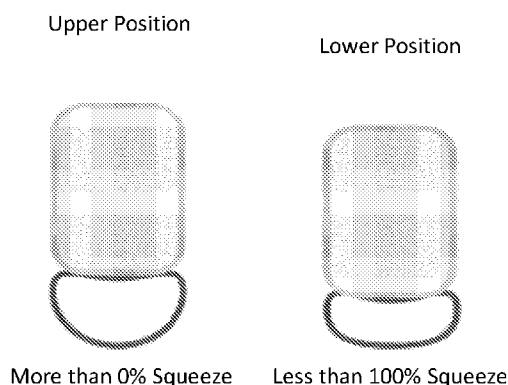


FIG. 2A

(57) Abstract: An infusion pump including a plunger, a proximal valve located proximally to the plunger, a distal valve located distally to the plunger, and a controller configured to trigger the position of the plunger, such that both in its upper position and its lower position, the plunger squeezes a section of an infusion tube, such that opposite sides of an inner surface of the section do not contact one another.



FLEX-STROKE INFUSION PUMP

FIELD OF THE INVENTION

The present invention relates generally to the field of medical devices for providing
5 fluid to a patient. More specifically, the present invention relates to infusion pumps
configured to prevent or compensate for degradation of infusion tubes operationally
connected to the pump.

BACKGROUND

10 Infusion pumps are configured to administer fluid to a patient via a conduit such as
an infusion tube or a cassette at high accuracy and often for a prolonged period of time.
Infusion tubes are accommodated in the infusion pump in such manner that a plunger can
squeeze the surface of the infusion tube, thereby causing delivery of the infusion fluid.

Infusion pumps administer fluids in ways that would be impractical and
15 expensive/unreliable if performed manually by nursing staff. For example, an infusion
pump assembly may repeatedly administer small quantities of an infusible fluid (e.g., 0.1
mL per hour). However, common disposable infusion tubes are prone to deform or rupture
when being continuously compressed, consequently affecting the precision of the delivery.

20 SUMMARY OF THE INVENTION

The hereindisclosed infusion pump advantageously includes a controller
configured to control the position of a plunger in such manner that an infusion tube
connected to the infusion pump remains partially squeezed during essentially the entire
operation of the pump.

That is, in its upper position (also referred to herein as an upper squeezing position) the plunger mildly squeezes the infusion tube, such that opposite sides of an inner surface of the infusion tube do not contact each other. This is as opposed to common infusion pumps, which in their upper position (also referred to herein as an uppermost position) do not squeeze the infusion tube; in fact, the plunger is typically elevated to a position in which it does not touch the infusion tube's outer surface.

As used herein, the term "mildly squeezing" refers to the plunger pressing upon the infusion tube sufficiently to cause a change in the shape of the infusion tube's inner lumen, as compared to a fully relaxed tube. According to some embodiments, at its upper squeezing position, when mildly squeezed, the infusion tube is more than 0% and less than 10% squeezed, as compared to a fully squeezed infusion tube. According to some embodiments, at its upper squeezing position, when mildly squeezed, the infusion tube is more than 5% and less than 10% squeezed, as compared to a fully squeezed infusion tube.

In the plunger's lower position (also referred to herein as a lower squeezing position), the squeezing of the infusion tube is increased, yet still the opposite sides of the inner surface of the infusion tube do not contact each other. Again, this is different than common infusion pumps, which typically are configured to squeeze the infusion tube to a maximum (also referred to herein as a lowermost position), i.e. such that the opposite sides of the inner surface of the infusion tube become basically aligned. According to some embodiments, in its lower squeezing position, the infusion tube is less than 100% squeezed and more than 80% squeezed, as compared to a fully squeezed infusion tube. According to some embodiments, in its lower squeezing position, the infusion tube is less than 95% squeezed and more than 80% squeezed, as compared to a fully squeezed infusion tube.

Advantageously switching between intermediate rather than extreme positions ensures accurate delivery even during prolonged delivery.

Complete squeezing of the infusion tube causes bottoming out and high stress to the tubing walls, which in turn leads to continuous degradation and impaired accuracy over time. This is particularly a problem when utilizing DEHP-free PVC, since PVC is an

overdamped spring that does not truly follow the plunger, as opposed to, for example, silicon tubes. Utilizing a less severe lower position advantageously prevents such degradation.

In addition, due to the plunger executing a mild squeeze even in the upper position
5 (deeper upper position of the plunger), the tube follows the plunger to the upper position and the springiness of the tubing is thus maintained throughout the pumping cycle. As a result, the need for incorporating complicated algorithms in an attempt to compensate for changes in flow rate over time is obviated. In fact, the flow rate stability of the hereindisclosed infusion pump is far superior to that of infusion pumps utilizing flow rate
10 compensation algorithms as further demonstrated hereinbelow.

According to some embodiments, the infusion pump, disclosed herein, is further configured to determine a wait period during which the plunger "waits" in its (deep) upper position, prior to the opening of the infusion pump's downstream valve. This allows the infusion tube to fully engage the plunger prior to the opening of the downstream valve, and
15 thus increases accuracy, as the volume of the tube is constant. In addition, an ascending of the infusion tube whilst the downstream valve is open, causing liquids to be extracted from the patient, is beneficially prevented.

According to some embodiments, during the intake phase (suction of liquid from an IV bag or syringe), the plunger can be raised to a position above the upper position and
20 then descended back to the upper position, mildly squeezing the infusion tube. This does not only allow more room for relaxation of the infusion tube, but also enables pumping a small bolus into the syringe, thus reducing the vacuum that is created during the intake.

Advantageously the controller may be configured to calibrate and/or optimize the upper and lower squeezing positions of the plunger, thus facilitating operation with
25 infusion tubes of different dimensions and consistencies.

According to some embodiments, there is provided an infusion pump comprising a plunger; a proximal valve located proximally to said plunger; a distal valve located distally to said plunger; and a controller configured to control infusion fluid delivery to the subject

and infusion fluid intake from a reservoir (also referred to as an infusion source). The controlling of the intake of fluid comprises: closing of said distal valve, opening of said proximal valve, moving of said plunger to an upper squeezing position, in which upper squeezing position of said plunger is configured to partially squeeze an infusion tube, while
5 facilitating intake of fluid; and determining a “wait” period, following the intake, during which wait period said plunger remains at said upper squeezing position, thereby ensuring full recovery of the tube to engagement of the infusion tube with the plunger. The controlling delivery comprises: closing of said proximal valve and opening of said distal valve, while said plunger is at the upper squeezing position, descending of said plunger
10 from the upper squeezing position to a lower squeezing position, wherein at both the upper squeezing position and the lower squeezing position, said plunger is configured to squeeze a section of an infusion tube, such that opposite sides of an inner surface of said section do not contact one another, thereby facilitating delivery of an essentially constant volume of infusion fluid to the subject regardless of a potential degradation of the infusion tube.

15 According to some embodiments, the plunger is configured to contact an outer surface of the infusion tube from the end of intake to end of delivery operation thereof.

According to some embodiments, at the lower squeezing position, the plunger is configured to squeeze the section of the infusion tube to form a first inner tube cross section and wherein, at the upper squeezing position, the plunger is configured to squeeze the
20 section of the infusion tube to form a second inner tube cross section, wherein the second inner tube cross section is larger than the first inner tube cross section and smaller than a cross section of the infusion tube, when not-squeezed.

According to some embodiments, the infusion pump further comprises a motor in communication with the controller, the motor configured to operate the plunger. According
25 to some embodiments, the motor is further configured to operate the proximal valve, the distal valve or both. Additionally or alternatively, the infusion pump further comprises a second motor configured to operate the proximal valve, the distal valve or both.

According to some embodiments, the infusion tube is a DEHP-free PVC infusion tube.

According to some embodiments, the controller is configured to calibrate the upper squeezing position and the lower squeezing position of the plunger according to
5 dimensions of the infusion tube.

According to some embodiments, controlling the intake of infusion fluid further comprises initially positioning of the plunger to a position above the upper squeezing position followed by a descending of the plunger to the upper squeezing position, while the proximal valve is open, thereby allowing residual fluid to backflow towards the
10 reservoir.

According to some embodiments, the wait period has a maximum duration based on and/or defined by the flow continuity and flow rate.

According to some embodiments, there is provided an infusion pump comprising: a plunger; a proximal valve located proximally to the plunger; a distal valve located distally
15 to the plunger; and a controller configured to control an infusion fluid delivery to the subject and an infusion fluid intake from a reservoir. Controlling the intake of fluid comprises: closing of said distal valve, opening of said proximal valve, moving of the plunger from the lower position to the upper position and above an upper squeezing position; and descending of the plunger to the upper squeezing position, in which upper
20 squeezing position the plunger is configured to partially squeeze an infusion tube, while allowing intake of infusion fluid. Controlling the intake of infusion fluid further comprises determining a “wait” period, following the intake, during which wait period the plunger remains at the upper squeezing position or above it, thereby ensuring engagement of the infusion tube with the plunger.

According to some embodiments, controlling the delivery of the infusion fluid
25 comprises: closing of the proximal valve and opening of the distal valve, while the plunger is at the upper squeezing position, descending of the plunger from the upper squeezing position to a lower squeezing position, wherein at both the upper squeezing position and

the lower squeezing position, the plunger is configured to squeeze a section of an infusion tube, such that opposite sides of an inner surface of the section do not contact one another, thereby facilitating delivery of an essentially constant volume of infusion fluid to the subject regardless of a potential degradation of the infusion tube.

5 According to some embodiments, the plunger is configured to contact an outer surface of the infusion tube section during the entire delivery thereof.

 According to some embodiments, the infusion pump further comprises a motor in communication with the controller, the motor configured to operate said plunger. According to some embodiments, the motor is further configured to operate the proximal
10 valve, the distal valve or both. Additionally or alternatively, the infusion pump further comprises a second motor configured to operate the proximal valve, the distal valve or both.

 According to some embodiments, the infusion tube is a DEHP-free PVC infusion tube.

15 Certain embodiments of the present disclosure may include some, all, or none of the above advantages. One or more technical advantages may be readily apparent to those skilled in the art from the figures, descriptions and claims included herein. Moreover, while specific advantages have been enumerated above, various embodiments may include all, some or none of the enumerated advantages.

20 In addition to the exemplary aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the figures and by study of the following detailed descriptions.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Examples illustrative of embodiments are described below with reference to figures attached hereto. In the figures, identical structures, elements or parts that appear in more than one figure are generally labeled with a same numeral in all the figures in which they

appear. Alternatively, elements or parts that appear in more than one figure may be labeled with different numerals in the different figures in which they appear. Dimensions of components and features shown in the figures are generally chosen for convenience and clarity of presentation and are not necessarily shown in scale. The figures are listed below.

5 **FIG. 1A** schematically illustrates upper and lower positions of prior art plungers;

FIG. 1B shows exemplary photos of a DEHP-free PVC infusion tube prior to use (left panel), and during use with a prior art plunger at its lower position (center panel) and its upper position (right panel);

FIG. 2A schematically illustrates upper and lower positions of the hereindisclosed
10 plunger; according to some embodiments;

FIG. 2B shows exemplary photos of a DEHP-free PVC infusion tube prior to use (left panel), and during use with the hereindisclosed plunger at its lower position (center panel) and its upper position (right panel);

FIG. 3 schematically illustrates an infusion pump with a plunger having
15 intermediate squeezing positions, according to some embodiments;

FIG. 4 is an illustrative flowchart for operating an infusion pump, according to some embodiments;

FIG. 5A shows the flow rate over time obtained using the hereindisclosed infusion pump (NatIV);

20 **FIG. 5B** shows the flow rate over time obtained using a prior art infusion pump including compensation algorithm.

DETAILED DESCRIPTION

 In the following description, various aspects of the disclosure will be described. For
25 the purpose of explanation, specific configurations and details are set forth in order to

provide a thorough understanding of the different aspects of the disclosure. However, it will also be apparent to one skilled in the art that the disclosure may be practiced without specific details being presented herein. Furthermore, well-known features may be omitted or simplified in order not to obscure the disclosure.

5 According to some embodiments, there is provided an infusion pump including a plunger; a proximal valve located proximally to the plunger; a distal valve located distally to the plunger; and a controller configured to control an infusion fluid delivery to the subject, wherein controlling delivery comprises triggering closing of the proximal valve, while the plunger is at an upper squeezing position, and triggering descending of the
10 plunger from the upper squeezing position to a lower squeezing position, wherein at both the upper squeezing position and the lower squeezing position, said plunger is configured to squeeze a section of an infusion tube, such that opposite sides of an inner surface of said section do not contact one another, thereby facilitating delivery of an essentially constant volume of infusion fluid to the subject regardless of a potential degradation of the infusion
15 tube.

 As used herein, the term "upper squeezing position" refers to a position of a plunger at which an infusion tube is mildly squeezed (i.e. higher than a position at which the tube is not squeezed), without having the opposite sides of an inner surface of the squeezed section contacting one another. According to some embodiments, the delivery phase of the
20 infusion pump is initiated at "upper squeezing position".

 As used herein, the term "lower squeezing position" refers to a position of the plunger at which an infusion tube is squeezed to a larger extent as compared to the upper squeezing position, yet still without having the opposite sides of an inner surface of the squeezed section contacting one another. According to some embodiments, the delivery
25 phase of the infusion pump is initiated at "upper squeezing position".

 As used herein, the term "degradation" may refer to the tube losing its springiness, becoming deformed, bottoming out, or otherwise changing its shape or consistency in a manner affecting the drug delivery accuracy. According to some embodiments, the infusion tube may be a DEHP-free PVC infusion tube, a DEHP containing infusion tube, a

polyethylene (PE) tube, a silicone tube, or the like. Each possibility is a separate embodiment.

As used herein, the term "infusion fluid" may refer to any fluid delivered to the patient such as, but not limited to, insulin, nutrients, saline solution, antibiotics, analgesics, anesthetics, hormones, vasoactive drugs, and chelation drugs, and any other therapeutic fluids or combination of fluids.

According to some embodiments, the plunger is configured to contact an outer surface of the infusion tube section during essentially the entire operation of the infusion pump. According to some embodiments, the plunger is configured to contact an outer surface of the infusion tube section during essentially the entire phase of delivery of the infusion fluid to the subject. According to some embodiments, the plunger is configured to some extent squeeze the infusion tube section, without having the opposite sides of an inner surface of the squeezed section contacting one another, during essentially the entire operation of the infusion pump. According to some embodiments, the plunger is configured to some extent squeeze the infusion tube section, without having the opposite sides of an inner surface of the squeezed section contacting one another, during essentially the entire phase of delivery of the infusion fluid to the subject. According to some embodiments, the plunger does not facilitate full relaxation of the infusion tube at any point of operation. According to some embodiments, the plunger does not fully squeeze/press the infusion tube at any point of operation.

As used herein, the term "entire" may refer to at least, at least 95% or at least 98% of the operation of the infusion pump/of the delivery phase. It is thus understood that briefly elevating the plunger during operation may be within the scope of this disclosure.

As used herein, the term "to some extent" with referral to the squeezing of the infusion tube refers to a squeezing of the infusion tube rendering the cross section of the squeezed section's lumen smaller than that of the infusion tube when non-squeezed, without having the opposite sides of an inner surface of the squeezed section contacting one another.

According to some embodiments, at the upper squeezing position, the plunger is configured to squeeze the section of the infusion tube to form a first inner tube cross section and wherein at the lower squeezing position, the plunger is configured to squeeze the section of the infusion tube to form a second inner tube cross section, wherein the second
5 inner tube cross section is smaller than the first inner tube cross section and larger than a cross section of the infusion tube when non-squeezed.

According to some embodiments, the inner tube cross section of the infusion tube when the plunger is in its upper position is 50%-90% the size of the inner tube cross section of the infusion tube when non-squeezed. Each possibility is a separate embodiment.

10 According to some embodiments, the inner tube cross section of the infusion tube when the plunger is in its lower position is between 50%-10%, larger than the size of the inner tube cross section. Each possibility is a separate embodiment.

Any combination of upper and lower squeezed positions is a specific embodiment.

According to some embodiments, for a typical tube of 3mm inner diameter and a
15 wall thickness of 0.5mm, a typical upper squeezing position, of the plunger is positioned about 0.8mm to 1.8mm, lower than the diameter of a non-squeezed tube. Each possibility is a separate embodiment.

According to some embodiments, for the same tube defined above, the lower squeezing position of the plunger is positioned about 2.0mm-2.8mm, below the non-
20 squeezed tube. Each possibility is a separate embodiment.

According to some embodiments, the infusion pump is configured to maintain an essentially constant flow rate during the entire delivery of an infusion fluid. As used herein, the term "essentially constant" refers to a flow rate changing by less than 2% during the entire delivery. As a non-limiting example, the infusion pump is configured to maintain a
25 delivery of an infusion fluid at a flow rate of 1mL/hour $\pm$ 0.01mL for at least 20, at least 36 or at least 96 hours.

According to some embodiments, the controller is further configured to control the intake of an infusion fluid from a reservoir, such as, but not limited to, an IV-bag or a syringe. According to some embodiments, controlling the intake of the infusion fluid comprises triggering opening of the proximal valve, closing of the distal valve and elevating the plunger to the upper squeezing position. According to some embodiments, during the intake phase, the plunger may initially be elevated to a position above the upper squeezing position for a brief moment (e.g. 1sec or less) and then lowered back to the upper squeezing position. This may advantageously allow more room for the infusion tube to assume a relaxed configuration. In addition, when using a syringe as the reservoir, the initial elevation of the plunger to a position above the upper squeezing position prior to assuming the upper squeezing position may pump a small bolus into the syringe, thus reducing the residual vacuum left in the syringe at the end of the intake.

According to some embodiments, the pump further includes a motor in communication with the controller, the motor configured to operate the plunger. According to some embodiments, the motor may further be configured to operate the proximal valve, the distal valve or both. Alternatively, the pump may include one or two additional motors configured to operate the proximal valve, the distal valve or both. According to some embodiments, the controller may control the operation of the motor, thereby determining the exact position of the plunger. This may advantageously allow calibrating the upper and lower squeezing positions vis-à-vis the floor against which the infusion tube is squeezed according to dimensions and/or consistency of the infusion tube.

According to some embodiments, the controller may further be configured to determine a “wait” period, during which wait period the plunger remains at the upper squeezing position, thereby ensuring full engagement of the infusion tube with the plunger, prior to the opening of the infusion pump’s downstream valve. This advantageously increases the accuracy of infusion fluid delivery in that the volume delivered remains constant even if the infusion tube has undergone degradation. Furthermore, due to the infusion tube fully engaging the plunger, a persistent ascending of the infusion tube after opening of the downstream valve is essentially prevented. Extraction of liquids from the patient is prevented. The length of the wait depends on the flow continuity requirements

and the flow rate. For low flow rates (1-10mL/hr) and flow continuity of bolus every 20sec, the wait can last up to 18sec. For high flow rates, the wait time is shorter (e.g. about 10 sec) and for very high flow rates (999mL/hr) it may last less than 1 second. The long wait is particularly advantageous for low flow rates where the tube squeeze duty cycle is very long.

According to some embodiments, the wait period may be at least two seconds, or at least 5 seconds. According to some embodiments, the duration of the wait is dependent on the flow rate of the infusion fluid and/or the length of the plunger.

According to some embodiments, there is provided a method of operation of an infusion pump, the method comprising;

providing/utilizing an infusion pump comprising a plunger; a proximal valve located proximally to the plunger and a distal valve located distally to the plunger;

triggering opening of the proximal valve,

triggering closing of the distal valve; and

triggering the positioning of the plunger to an upper squeezing position at which the infusion tube positioned within the infusion pump is mildly squeezed yet without having opposite sides of the inner surface of its squeezed section contacting one another, thereby causing intake of fluid from a reservoir;

positioning/holding the plunger in the upper squeezing position;

triggering closing of the proximal valve, while the plunger is at the upper squeezing position; and

triggering descending of the plunger from the upper squeezing position to a lower squeezing position, at which the infusion tube is further squeezed, yet still without having opposite sides of the inner surface of its squeezed section contacting one another, thereby facilitating delivery of an essentially constant volume of the infusion fluid to a subject, regardless of a potential degradation of the infusion tube.

According to some embodiments, the infusion tube is at no point of operation fully squeezed/pressed by the plunger.

According to some embodiments, the method may further include briefly elevating the plunger to a position above the upper squeezing position, (while the proximal valve is open, and the distal valve closed) prior to the positioning of the plunger at the upper squeezing position, thereby allowing a small bolus of infusion fluid to flow into the syringe, thus reducing the vacuum created therein during the intake, as well as allowing more room for the infusion tube to assume a relaxed configuration.

According to some embodiments, the method may further include determining a “wait” period configured to ensure full engagement of the infusion tube with the plunger, wherein during the wait period the plunger remains at the upper squeezing position, prior to the opening of the infusion pump's downstream valve.

Reference is now made to **FIG. 1A**, which schematically illustrates upper and lower positions of prior art plungers. As shown in the figure, typical plungers are configured to assume an upper position (also referred to herein as an uppermost position) at which the infusion tube is fully relaxed (during fluid intake) and a lower position (also referred to herein as a lowermost position) at which the infusion tube is fully squeezed (during infusion fluid delivery).

As evident from **FIG. 1B** which shows exemplary photos of a DEHP-free PVC infusion tube prior to use (left panel), during use at its lower position (center panel) and during use at its upper position (center panel); during use the infusion tube undergoes degradation, i.e. loses its springiness and/or shape. That is, when the plunger fully squeezes the infusion tube, high stress is incurred, and the tube tends to bottom out. With time, when the plunger is elevated to its uppermost position (during intake), the tube acts as an overdamped spring and fails to fully engage the plunger. This, on the one hand, results in a lower volume of intake and thus to inaccurate/insufficient infusion fluid delivery, which at times may be harmful and even hazardous to the patient's health. To solve this problem, prior art pumps have been provided which include complex algorithms compensating for the changes in flow rate. However, as further demonstrated hereinbelow, such algorithms

fail to accurately predict the changes in flow rate and variations therein are still prevalent. In addition, a continuous ascending of the tube towards the plunger may occur after the downstream valve has been opened, thus causing liquids to be extracted from the patient.

Reference is now made to **FIG. 2A**, which schematically illustrates upper and lower positions of the hereindisclosed plungers. As shown in the figure, the hereindisclosed plunger is configured to assume an upper position (also referred to herein as an upper squeezing position) at which the infusion tube is mildly squeezed (during fluid intake) and a lower position (also referred to herein as a lower squeezing position) at which the infusion tube is squeezed to a larger extent than at the upper squeezing position yet without having opposite sides of the tube's inner surface contacting each other (during infusion fluid delivery).

Advantageously and as evident from **FIG. 2B** which shows exemplary photos of a DEHP-free PVC infusion tube prior to use (left panel), and during use with the hereindisclosed plunger at its lower position (center panel), and its upper position (right panel); a crushing of the tube's wall is avoided, and the springiness of the tube is much less affected. That is, at the lower squeezing position, much less stress is incurred on the tubing, and the bottoming out obtained when fully squeezing the tube is essentially non-existent. In addition, due to the fact that the plunger squeezing the tube even at its upper squeezing position ensures that the tube engages the plunger at all times. As a result, the delivery flow rate remains constant during the entire use, and the need for compensating algorithms is obviated. In addition, since full engagement of the tube with the plunger is ensured, the continuous ascending of the tube towards the plunger, after opening of the downstream valve, is largely prevented. Altering between two squeezed states strengthens the minimum strength of the tube spring in the upper position and reduces the maximum tube squeeze at the lower position to reduce the degradation.

Reference is now made to **FIG. 3** which schematically illustrates an infusion pump **300** with a plunger **310** having intermediate squeezing positions, according to some embodiments. Infusion pump **300** includes a proximal valve **320**, also referred to herein as an inlet valve, positioned proximally/upstream to plunger **310** and configured to allow flow

of infusion fluid from a reservoir (not shown) to an infusion tube **350**. Infusion pump **300** further includes a distal valve **325**, also referred to herein as an outlet valve, positioned distally/downstream to plunger **310** and configured to allow flow of infusion fluid from infusion tube **350** to a patient (not shown). The positioning of plunger **310**, proximal valve **320** and distal valve **325** are carried out by motor **340** and associated cam shaft **342**, although other embodiments, according to which positioning of plunger **310**, proximal valve **320** and distal valve **325** is executed by separate motors, are also possible and within the scope of this disclosure. During intake of infusion fluid from a reservoir, a controller (not shown) is configured to control operation of motor **340** and associated cam shaft **342**, which in turn brings about opening of proximal valve **320**, closing of the distal valve **325**, and positioning of plunger **310** in an upper squeezing position, at which infusion tube **350**, positioned within infusion pump **300**, is mildly squeezed, yet allowing infusion fluid intake. During delivery of infusion fluid, the controller triggers motor **340** and associated cam shaft **342** to close proximal valve **320**, while plunger **310** is in its upper squeezing position; to open distal valve **325** and descending plunger **310** from the upper squeezing position to a lower squeezing position, at which the infusion tube is further squeezed, yet without having opposite sides of the inner surface of its squeezed section contacting one another, thereby facilitating delivery of an essentially constant volume of infusion fluid to the patient.

According to some embodiments, the controller may further be configured to define a “wait” period configured to ensure full engagement of infusion tube **350** with the plunger **310**, wherein, during the wait period, plunger **310** remains at the upper squeezing position, while distal valve **325** is open. As a non-limiting example, if the maximum no flow time is set to 20 seconds and the closing of the distal and opening of the proximal valves takes 3 seconds, the controller may be configured to retain plunger **310** at the upper squeezing position for an additional 17 seconds, prior to commencing delivery by lowering plunger **310** to the lower squeezing position after the valves are switched back to delivery position. The wait period ensures full engagement of infusion tube **350** with plunger **310** prior to infusion fluid delivery and thus guarantees that an exact and constant amount of infusion fluid is delivered to the patient. In addition, by preventing continuous ascending/relaxing

of infusion tube **350** during delivery (which may occur if full engagement between infusion tube **350** and plunger **310** is not achieved), liquid may be sucked from the patient into infusion tube **350**. This may in turn result in blood entering the catheter and the tube, and cause occlusions in the infusion tube. In addition, the blood in the tube is also often found visually unpleasant to the patient and his/her surroundings. Defining a wait period may be of particular importance for low flow rate delivery in which case infusion tube **350** is squeezed by plunger **310** (in its lower squeezing position) for a prolonged period of time (e.g. 1-3 hours depending on the plunger length, tube ID and flow rate). The intake of the infusion fluid has a short duration (a few seconds) and, without the wait, will not be sufficient to recover the tube to the original upper position of the plunger, hence, will reduce the intake volume.

According to some embodiments, the controller may be further configured to trigger an elevating of plunger **310** to a position above the upper squeezing position (but still somewhat squeezed), while proximal valve **320** is open, and distal valve **325** closed, such that lowering of plunger **310** to the upper squeezing position causes a small bolus of infusion fluid to flow into the reservoir. Such initial backflow may be particularly advantageous when the infusion source is a syringe, in that it enables reducing the residual vacuum created within the syringe.

Reference is now made to **FIG. 4** which is an illustrative flowchart **400** for operating an infusion pump, according to some embodiments.

Steps **410** to **450** are steps associated with intake of infusion fluid from a reservoir (also referred to herein as infusion source).

In step **410** an infusion tube is positioned within an infusion pump comprising a plunger, a proximal valve located proximally to the plunger, and a distal valve located distally to the plunger.

In step **420** an opening of the proximal valve and a closing of the distal valve is triggered, followed by a positioning of the plunger in an upper squeezing position at which the infusion tube is mildly squeezed (step **440**), yet without having opposite sides of the

inner surface of its squeezed section contacting one another, thereby causing intake of fluid from a reservoir.

Optionally, prior to positioning the plunger in its upper squeezing position, the method may include a step **430** in which the plunger is, for most of the wait time, elevated
5 to a position above the upper squeezing position, (while the proximal valve is open, and the distal valve closed). This step may be particularly advantageous when the reservoir is a syringe in that it allows a small bolus of infusion fluid to flow into the syringe, thus reducing the residual vacuum created therein during the intake.

Optionally, after intake of infusion fluid from the reservoir is completed, the
10 method may further include a step **450** at which the plunger “waits” at the upper squeezing position for the longest time the flow continuity and the flow rate permits, so as to ensure full engagement of the infusion tube with the plunger. According to some embodiments, the length of the wait period may depend on the length of the intake and may, for example, range between 2 seconds and 18 seconds when the required flow continuity is to have a
15 maximum delivery every 20 seconds. If the flow continuity is defined by 10 minutes of maximum no flow time, the wait can last 10 minutes minus a few seconds. The choice of wait is the longest possible under the specific flow continuity and flow rate requirements.

Steps **460** to **470** are steps associated with delivery of the infusion fluid to a patient.

In step **460** the plunger is held in the upper squeezing position while closing of the
20 proximal valve and opening of the distal valve is triggered. Subsequently, in step **470**, a descending of the plunger from the upper squeezing position to a lower squeezing position is triggered, thereby causing the infusion tube to be further squeezed yet still without having opposite sides of the inner surface of its squeezed section contacting one another. As a result, delivery of an essentially constant volume of the infusion fluid to a subject is
25 facilitated, regardless of a potential degradation of the infusion tube.

EXAMPLES

Example 1 – Flow rate stability

In order to evaluate the flow rate stability of the hereindisclosed infusion pump a comparative study was set up. The study evaluated the flow rate over time of an infusion fluid delivered by the hereindisclosed infusion pump (Avoset) as compared to that obtained using a known infusion pump including a compensation algorithm configured to mathematically compensate for changes in flow rate caused by tube degradation.

As seen from **FIG. 5A**, when utilizing the hereindisclosed infusion pump for delivery of an infusion fluid at a flow rate of 1mL/hr, 40 hours, a constant 1mL/hr flow rate is obtained during the entire course of the delivery. This, as opposed to a prior art infusion pump, which despite incorporating compensation algorithms, has a declined flow rate over time, such that 30 hr after commencing the delivery, a flow rate of 0.9 mL/hr instead of 1mL/hr is obtained, as seen in **FIG. 5B**.

This result clearly emphasizes the unexpected and convincing advantage of the hereindisclosed infusion pump, which is capable of ensuring a constant delivery of infusion fluid for 40 hours and more.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, or components, but do not preclude or rule out the presence or addition of one or more other features, integers, steps, operations, elements, components, or groups thereof.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as “processing”, “computing”, “calculating”, “determining”, “estimating”, or the like, refer to the action and/or processes of a computer or computing system, or similar electronic

computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities within the computing system's registers and/or memories into other data similarly represented as physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices.

5 Embodiments of the present invention may include apparatuses for performing the operations herein. This apparatus may be specially constructed for the desired purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but not limited to, any type of read-only
10 memories (ROMs), random access memories (RAMs), electrically programmable read-only memories (EPROMs), electrically erasable and programmable read only memories (EEPROMs), or any other type of media suitable for storing electronic instructions, and capable of being coupled to a computer system bus.

 The processes and displays presented herein are not inherently related to any
15 particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct a more specialized apparatus to perform the desired method. The desired structure for a variety of these systems will appear from the description below. In addition, embodiments of the present invention are not described with reference to any particular programming
20 language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the inventions as described herein.

 The invention may be described in the general context of computer-executable instructions, such as program modules, being executed by a computer. Generally, program modules include routines, programs, objects, components, data structures, and so forth,
25 which perform particular tasks or implement particular abstract data types. The invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote computer storage media including memory storage devices.

While a number of exemplary aspects and embodiments have been discussed above, those of skill in the art will recognize certain modifications, additions and sub-combinations thereof. It is therefore intended that the following appended claims and claims hereafter introduced be interpreted to include all such modifications, additions and
5 sub-combinations as are within their true spirit and scope.

CLAIMS

What we claim is:

1. An infusion pump comprising:

5

a plunger;

a proximal valve located proximally to said plunger;

a distal valve located distally to said plunger; and

a controller configured to control an infusion fluid delivery to the subject and an infusion fluid intake from a reservoir,

10

wherein controlling the intake of fluid comprises:

closing of said distal valve,

opening of said proximal valve,

moving of said plunger to an upper squeezing position, in which upper squeezing position of said plunger is configured to partially squeeze an infusion tube, while facilitating intake of fluid; and

15

determining a “wait” period, following the intake, during which wait period said plunger remains at said upper squeezing position, thereby ensuring full recovery of the tube to engagement of the infusion tube with the plunger;

wherein controlling delivery comprises:

20

closing of said proximal valve and opening of said distal valve, while said plunger is at the upper squeezing position,

descending of said plunger from the upper squeezing position to a lower squeezing position,

25

wherein at both the upper squeezing position and the lower squeezing position, said plunger is configured to squeeze a section of an infusion tube, such that opposite sides of an inner surface of said section do not contact one another,

thereby facilitating delivery of an essentially constant volume of infusion fluid to the subject regardless of a potential degradation of the infusion tube.

2. The pump of claim 1, wherein said plunger is configured to contact an outer surface of the infusion tube from the end of intake to end of delivery operation thereof.

5 3. The pump of claim 1, wherein at the lower squeezing position, said plunger is configured to squeeze the section of the infusion tube to form a first inner tube cross section and wherein at the upper squeezing position, said plunger is configured to squeeze the section of the infusion tube to form a second inner tube cross section, wherein the second inner tube cross section is larger than the first inner tube cross section and smaller than a cross section of the infusion tube, when not-squeezed.

10 4. The pump of claim 1, further comprising a motor in communication with said controller, said motor configured to operate said plunger.

5. The pump of claim 4, wherein said motor is further configured to operate said proximal valve, said distal valve or both.

15 6. The pump of claim 4, further comprising a second motor configured to operate said proximal valve, said distal valve or both.

7. The pump of claim 1, wherein said infusion tube is a DEHP-free PVC infusion tube.

20 8. The pump of claim 1, wherein the controller is configured to calibrate the upper squeezing position and the lower squeezing position of the plunger according to dimensions of the infusion tube.

25 9. The infusion pump of claim 1, wherein controlling the intake of infusion fluid further comprises initially positioning of the plunger to a position above the upper squeezing position followed by a descending of the plunger to the upper squeezing position, while the proximal valve is open, thereby allowing residual fluid to backflow towards the reservoir.

10. The infusion pump of claim 1, wherein the wait period has a maximum duration based on the flow continuity and flow rate.

11. An infusion pump comprising:

a plunger;

5 a proximal valve located proximally to said plunger;

a distal valve located distally to said plunger; and

a controller configured to control an infusion fluid delivery to the subject and an infusion fluid intake from a reservoir,

wherein controlling the intake of fluid comprises:

10 closing of said distal valve,

opening of said proximal valve,

moving of the plunger from the lower position to the upper position and above an upper squeezing position;

15 and descending of said plunger to the upper squeezing position, in which upper squeezing position of said plunger is configured to partially squeeze an infusion tube, while allowing intake of infusion fluid.

12. The infusion pump of claim 11, wherein controlling the intake of infusion fluid further comprises determining a “wait” period, following the intake, during which wait period of said plunger remains at said upper squeezing position or above it, thereby ensuring engagement of the infusion tube with the plunger.

20

13. The infusion pump of claim 11, wherein controlling the delivery of the infusion fluid comprises:

closing of said proximal valve and opening of said distal valve, while said plunger is at the upper squeezing position,

25 descending of said plunger from the upper squeezing position to a lower squeezing position,

wherein at both the upper squeezing position and the lower squeezing position, said plunger is configured to squeeze a section of an infusion tube, such that opposite sides of an inner surface of said section do not contact one another, thereby facilitating delivery of an essentially constant volume of infusion fluid to the subject regardless of a potential degradation of the infusion tube.

5

14. The pump of claim 11, wherein said plunger is configured to contact an outer surface of the infusion tube section during the entire delivery thereof.

15. The pump of claim 11, further comprising a motor in communication with said controller, said motor configured to operate said plunger.

10

16. The pump of claim 15, wherein said motor is further configured to operate said proximal valve, said distal valve or both.

17. The pump of claim 15, further comprising a second motor configured to operate said proximal valve, said distal valve or both.

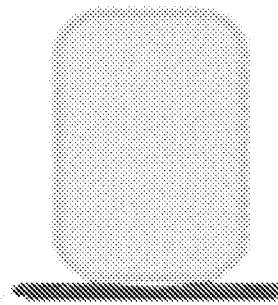
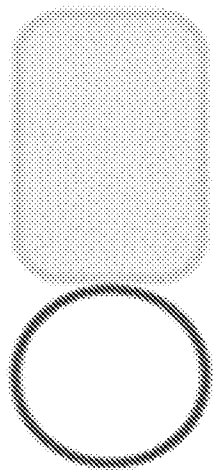
15

18. The pump of claim 11, wherein said infusion tube is a DEHP-free PVC infusion tube.

1/5

Upper Position

Lower Position



0% Squeeze

100% Squeeze

FIG. 1A

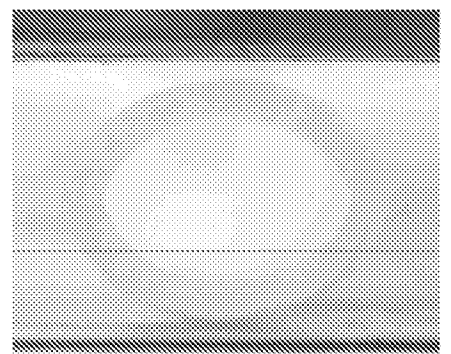
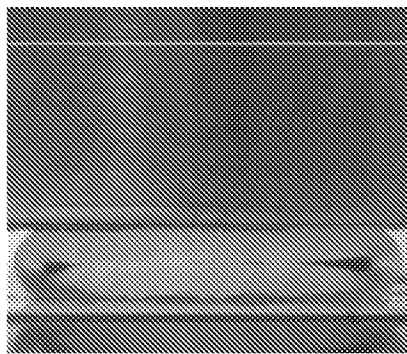
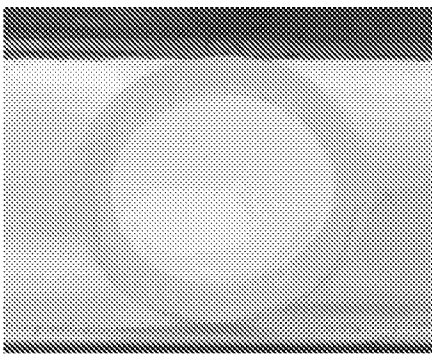


FIG. 1B

2/5

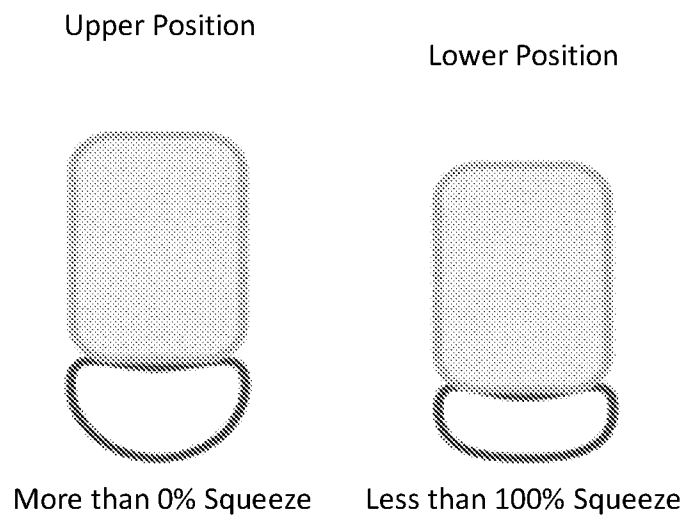


FIG. 2A

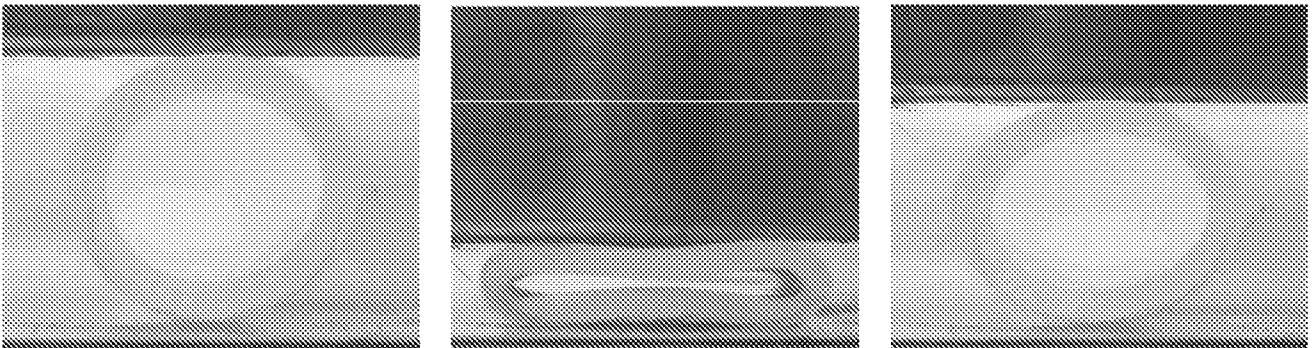


FIG. 2B

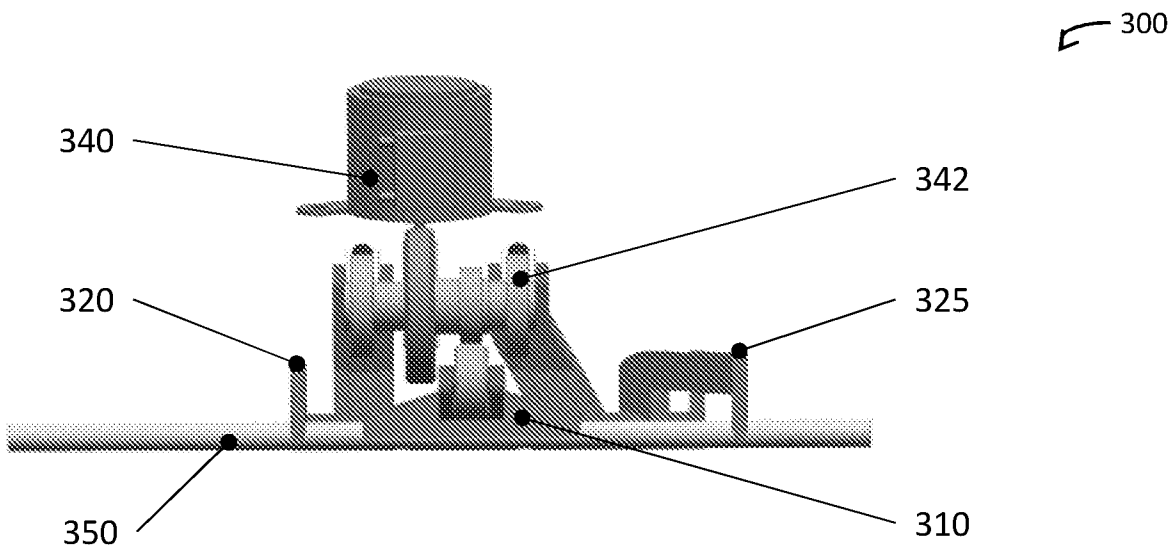


FIG. 3

4/5

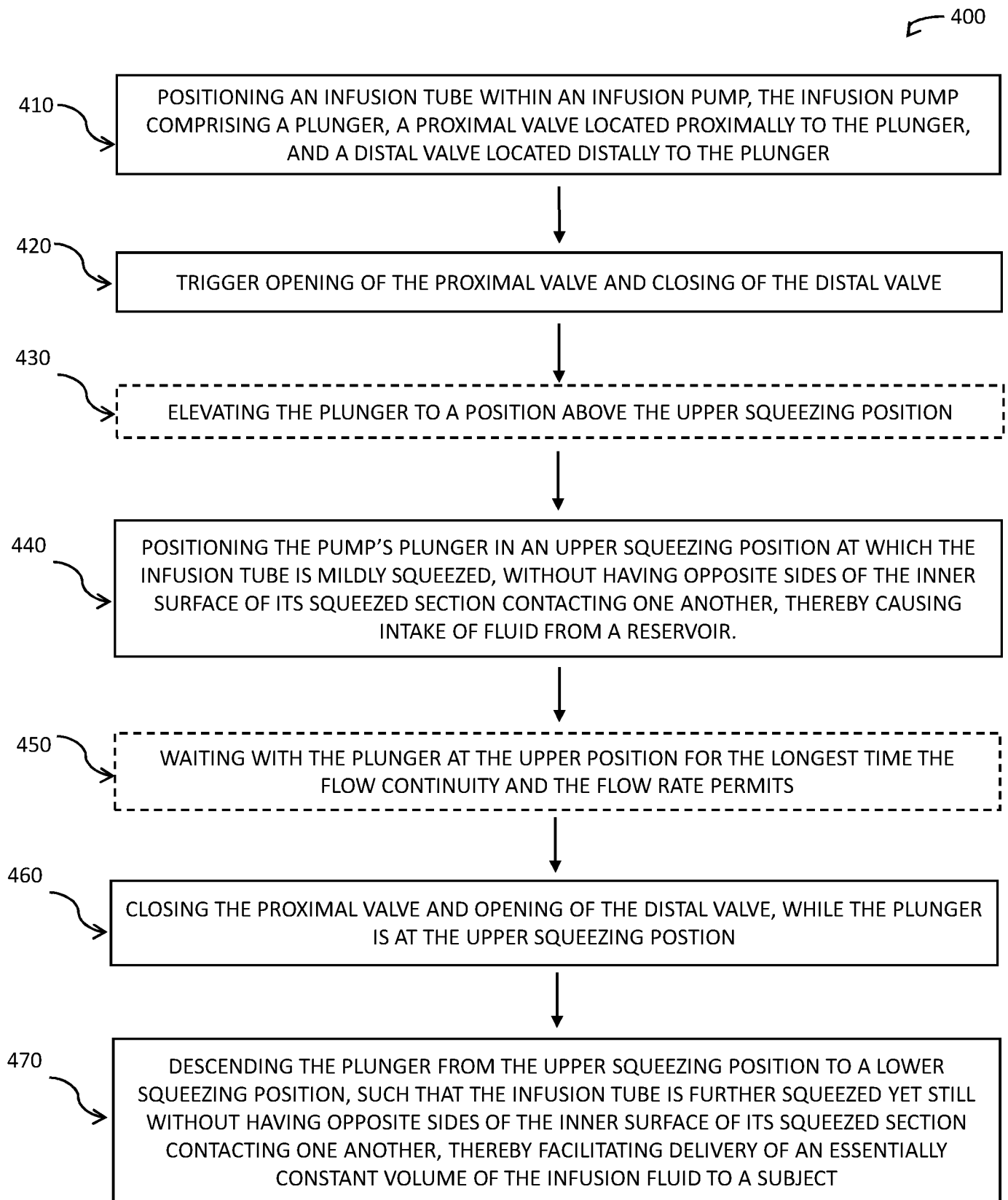


FIG. 4

5/5

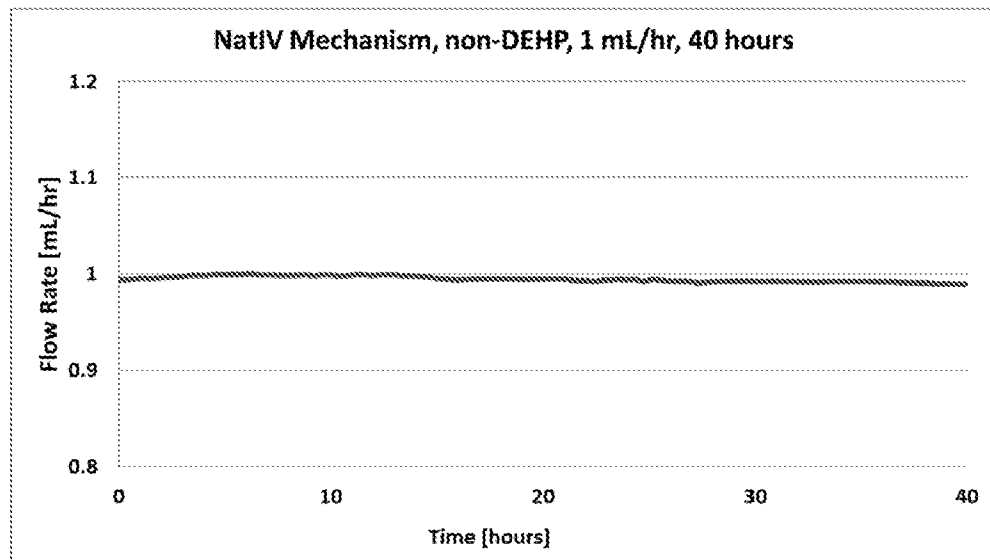


FIG. 5A

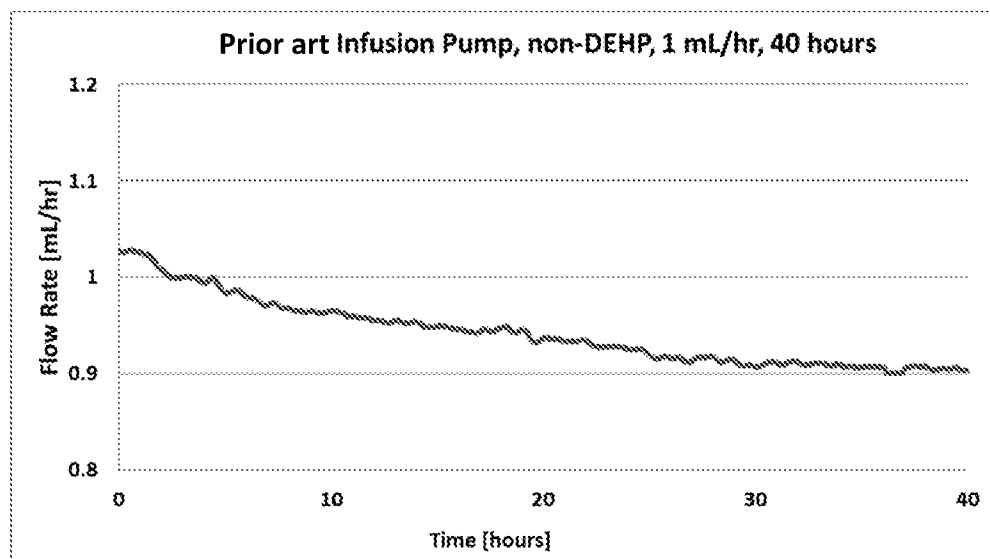


FIG. 5B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2018/050409

A. CLASSIFICATION OF SUBJECT MATTER IPC (2018.01) A61M 5/142, A61M 5/168, F04B 43/08 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC (2018.01) A61M, F04B Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Databases consulted: PatBase, Orbit		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5807322 A (GRASEBY MEDICAL LTD. [GB]) 15 Sep 1998 (1998/09/15) the whole document	1-18
A	US 2010/0106082 A1 (BAXTER INTERNATIONAL INC. [US]) 29 Apr 2010 (2010/04/29) the whole document	1-18
A	US 2013/0035659 A1 (SIGMA INTERNATIONAL GENERAL MEDICAL APPARATUS, LLC. [US]) 07 Feb 2013 (2013/02/07) the whole document	1-18
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 05 Aug 2018		Date of mailing of the international search report 05 Aug 2018
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616		Authorized officer SEGAL Liviu Telephone No. 972-2-5651782

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IL2018/050409

Patent document cited search report			Publication date	Patent family member(s)	Publication Date
US	5807322	A	15 Sep 1998	NONE	
-----			-----	-----	-----
US	2010/0106082	A1	29 Apr 2010	NONE	
-----			-----	-----	-----
US	2013/0035659	A1	07 Feb 2013	NONE	
-----			-----	-----	-----