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Evaluation of the FASTSTART mode for reducing start-up delay in syringe pump infusion systems[1]

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Summary

Objective: The aim of the study was to evaluate the IVAC® P7000 FASTSTART mode with regard to start-up performance in a 50-ml infusion syringe at a flow rate of 1 $ml.h^{-1}$.

Methods: The time from depression of the start button to first fluid flow (T_1) and to establishment of a pre-set flow rate (T_2) were gravimetrically recorded with and without FASTSTART and with and without priming of the infusion system with a 1-ml fluid bolus prior to connection of the infusion line to the patient.

Results: FASTSTART significantly reduced start-up times in the unprimed syringe pump infusion system from (mean [SD]) 9.4 (6.0) to 2.5 (3.5) min for T_1 and from 21.8 (9.8) to 9.4 (6.2) min for T_2 (all $p < 0.001$). The greatest improvement in shortening of T_1 and T_2 was obtained when the system was primed prior to starting ($p < 0.0001$). After priming the infusion system, FASTSTART shortened T_2 by some 50% from 1.4 (1.4) to 0.7 (0.6) min.

Conclusion: Our data indicate that the FASTSTART procedure is effective and that substantial improvements can be obtained by priming the system prior to starting.

Keywords: equipment; infusion systems; start-up performance; FASTSTART

Introduction

Start-up delays in syringe pumps are a well-known disadvantage of pressure-controlled infusion systems, and they are likely to be significant at low flow rates [1–3]. These delays are a result of mechanical gaps between the syringe and the syringe pump, of backlash in the gears, and of internal compliance of the syringe infusion pump assembly [3, 4].

Although mechanical gaps between syringe and pump can be taken up during priming of the system, some backlash in the gear may occur and compliance within the syringe pump system remains unaffected. Thus, it takes time to overcome the required driving pressure after starting the pump.

Recently, the FASTSTART mode has been developed and integrated into the IVAC P7000 syringe pump (Alaris Medical Systems, Hampshire, UK) as an optional feature that can be switched on and off. FASTSTART is not simply a fixed bolus at the beginning of each infusion but is an intelligent combination of the measurement of plunger force and line pressure, with a maximum volume determining the period for which FASTSTART is required. When an infusion is started, the system checks whether the drive has recently been declutched and the plunger force is below the FASTSTART threshold. When the force on the plunger or the line pressure exceeds pre-set limits, or when a maximum volume has been delivered, FASTSTART is terminated and the driver delivers at the set rate. The manufacturer claims that the effects of FASTSTART are twofold: reduction of drive gear slack and reduction in movement of the syringe barrel flanges to the left-hand side of the "V" slot, if the syringe is not primed on the pump [5].

The aim of the study was to evaluate the efficacy and safety of the FASTSTART procedure with different start-up performances and different syringe brands.

1 Financial Support: none / 2 pumps provided by local distributor for testing.

Methods

Setup

An IVAC infusion syringe (50-ml syringe, Alaris Medical Systems, San Diego, USA – Ref. 30602 N) was connected to a 2-m IVAC infusion line including a pressure-sensing disc (Syringe Extension Set, IVAC Medical Systems, Inc, San Diego, USA – Ref. G30402). The distal infusion line was connected to a stopcock followed by a 50-cm infusion line (PE-Infusion line, Clinico Medical GmbH, Bad Mersfeld, GER) providing the connection to a single-lumen 22 G central venous catheter (Certofix Mono Paed S110, B Braun, Melsungen, GER). The whole infusion syringe – infusion line – catheter assembly was flushed and care was taken to remove any air bubbles. The tip of the central venous catheter was immersed 13 cm below the fluid surface of a sampling glass filled with distilled water. The fluid surface was covered by a thin layer of oil to avoid fluid evaporation. Fluid delivery from the catheter tip into the sampling glass was measured using an electronic balance (sensitivity = 0.0001 g; AG 204-Delta-Range, Mettler Toledo, Schwerzenbach, Switzerland). The balance output was recorded by a personal computer employing MCPS V2.6-CAD software (Software GmbH, Mönchengladbach, GER). Before starting measurements, the syringe outlet was positioned at the level of the central venous catheter tip corresponding to a central venous pressure of 10 mm Hg. All measurements were performed at a flow rate of 1 $ml.h^{-1}$.

Experiments performed

In a first study we compared the start-up procedures in the IVAC infusion syringe using a two-by-two factorial design: after placing the syringe and the sensory disc in the syringe pump, the starting button was activated either with or without FASTSTART (first factor) and combined or not combined with priming (second factor) of the system prior to connection of the infusion line to the catheter. Priming of the infusion system included delivery of a 1-ml fluid bolus through the infusion line by depressing the bolus button on the syringe pump until a flushing volume of 1 ml was indicated by the pump display. To avoid repeated disconnection/connection of the infusion line and the catheter the fluid bolus was delivered through the outlet of the stopcock to ambient pressure. This procedure was considered as the bench equivalent to applying a 1-ml bolus from an already connected infusion line-infusion pump assembly to the patient or from the infusion line immediately prior to connection to the patient. In this part of the study the same syringe brand was used.

In the second part of the study we employed a three by two factorial design, to compare start-up times with and without FASTSTART (first factor), after priming the infusion systems, obtained with the following three syringe brands (second factor): IVAC infusion syringe (50-ml syringe, Alaris Medical Systems, San Diego, USA – Ref. 30602 N), CODAN infusion syringe (Single-use syringe, 50-ml, CODAN Medical ApS, Rodby, DK – Ref. 62.8455) and Fresenius infusion syringe (Injectomat syringe 50 ml, Fresenius AG, Bad Homburg, GER – Ref. 9000711).

All measurements were repeated in duplicate with three different syringes of the same type and with two syringe pumps obtained by the local distributor ($2\times3\times2$ measurements for each start-up procedure performed). The time from start to first fluid flow (T_1) and the time to achievement of pre-set flow delivery (T_2), as well as the amount of first-minute fluid effusate, were calculated from each run.

Statistical analysis

Start-up times T_1 and T_2 were compared using the different start-up procedures and different syringe brands in separate analyses. We employed two-way analysis of variance for each part of the study. For the first part of the study the factors were FASTSTART (yes/no) and priming (yes/no). In the second part the factors were FASTSTART (yes/no) and syringe type. In the latter analysis we also included a FASTSTART-syringe type interaction term. Because T_1 and T_2 values were not normally distributed, we repeated all analyses on the log-transformed values for T_1 and T_2 (after adding 0.5 sec to all values to allow logarithmic transformation of zero values). Where possible we also performed non-parametric tests (Kruskal-Wallis; e.g. syringe brands with FASTSTART). These analyses yielded similar results and are not presented in the results section. Post hoc analyses were carried out using Scheffe's adjustment for multiple comparisons. We tested the F distribution for significance in order to test the variances between the three syringe brands. A $p < 0.05$ was considered statistically significant. All analyses were performed with Statistical Analysis Software using PROC GLM (SAS Version 6.12, SAS Inc., Cary, NC, USA).

Results

In syringes not primed with a bolus, FASTSTART significantly reduced the time to first fluid flow (T_1) from (mean [SD]) 9.4 (6.0) to 2.5 (3.5) min ($p = 0.001$) and the time to achievement of pre-set flow (T_2) from 21.8 (9.8) to 9.4 (6.2) min ($p < 0.001$) (table 1). Priming the infusion system resulted in strikingly shorter start-up times ($p < 0.0001$) (table 1). In the primed IVAC syringe pump, all measurements of first fluid delivery were within 10 seconds irrespective of syringe brand and of whether FASTSTART was employed or not ($p = 0.99$). However, FASTSTART halved T_2 in primed syringes ($p = 0.01$). The time to achievement of pre-set fluid delivery (T_2) differed considerably in the three infusion syringe brands tested ($F = 3.65$, d.f. = 7/63, $r^2 = 0.29$, $p = 0.0023$). The CODAN syringe exhibited the lowest and the Fresenius syringe the highest values ($p = 0.0008$); data are summarised in table 2. Observed differences between the two syringe pumps were not statistically significant ($p = 0.21$). No differences between individual syringes of the same brand were recorded ($p = 0.20$).

When syringes were primed, there was no difference in first-minute effusate whether FASTSTART was employed or not (table 2). However, first-minute effusate differed considerably among the three syringe brands despite priming ($F = 12.1$, d.f. = 2/64, $p < 0.0001$), with the CODAN syringe yielding the highest first-minute effusate (adjusted

Table 1

Time from starting infusion pump to first fluid delivery (T_1), time of first achievement of pre-set flow (T_2), and first-minute effusate during different start-up procedures at an infusion rate of 1 ml.h^{-1} using an IVAC 50-ml infusion syringe. Results are shown as mean (SD).

	IVAC 50-ml syringe (selected pairwise comparisons)								
	no priming / no FS	no priming / FS	p*	no priming / no FS	priming / no FS	p*	priming / no FS	priming / FS	p*
N samples	12	12	–	12	12	–	12	12	–
T_1 (min)	9.36 (5.98)	2.51 (3.47)	0.001	9.36 (5.98)	0.17 (0)	<0.001	0.17 (0)	0.17 (0)	1
T_2 (min)	21.75 (9.8)	9.44 (6.24)	<0.001	21.75 (9.8)	1.36 (1.41)	<0.001	1.36 (1.41)	0.74 (0.6)	0.32
1st minute effusate (µl)	0	6.0 (7.7)	<0.001	0	14.3 (6.9)	<0.001	14.3 (6.9)	15.7 (6.9)	0.78

* Non-parametric tests, no adjustment of p-value for multiple comparisons FS = FASTSTART

Table 2

Time from starting infusion pump at an infusion rate of 1ml.h^{-1} to first fluid delivery (T_1), time to first pre-set flow (T_2), and first-minute effusate in three different syringe brands with and without FASTSTART after priming the infusion system. Results are shown as mean (SD). Results for T_2 differed significantly between syringes (all p = 0.0023) and between FASTSTART/no FASTSTART (all p = 0.01) but did not differ for T_1. Boluses were significantly different across syringes (all p <0.0001) but not according to whether FASTSTART was switched on or off.

	CODAN 50-ml syringe		IVAC 50-ml syringe		Fresenius 50-ml syringe	
	priming	priming + FS	priming	priming + FS	priming	priming + FS
N samples	12	12	12	12	12	12
T_1 (min)	0.17 (0)	0.17 (0)	0.17 (0)	0.17 (0)	0.17 (0)	0.18 (0.05)
T_2 (min)	0.58 (0.49)	0.27 (0.13)	1.36 (1.41)	0.74 (0.60)	2.17 (2.13)	1.01 (0.59)
1st minute effusate(µl)	17.7 (8.1)	20.9 (6.9)	14.3 (6.9)	13.7 (6.9)	10.8 (7.4)	12.6 (9.0)

mean 19.2 µl). In the IVAC and Fresenius syringes mean values (adjusted means 14.0 µl and 11.7 µl respectively) were lower than the expected amount of fluid delivered per minute at 1ml.h^{-1} flow rate (16.7 µl.min^{-1}) (table 2).

Discussion

We studied the efficacy of the FASTSTART procedure on start-up performance in different settings and syringe brands. The main finding was that FASTSTART significantly reduced start-up times in the unprimed syringe and halved the time to first achievement of pre-set flow rate in primed syringes.

Many users are unaware that at low flow rates start-up times may represent a major problem. Unfortunately, the infusion pump alarm will not be activated under these circumstances and the pump will indicate correct operation. This means that the patient may be deprived of vital medication for some minutes after the start of an infusion.

Insertion of an infusion syringe already connected to the patient into the syringe pump and subsequently starting the pump results in considerable start-up delays, as demonstrated by our data. To address this problem, it is recommended that after the syringe is placed correctly in the pump the bolus button of the pump be manipulated long enough to allow all the slack to be taken up before connecting the extension set to the patient. This will have occurred when fluid is seen flowing out of the extension set. Provided the syringe is not disturbed, there will be minimal delay in delivery of fluid when the pump is started. In the present study, priming the syringe proved to be the most effective manoeuvre.

When the system was not primed before starting the syringe pump, FASTSTART effectively shortened the time from activation of the pump to first and subsequent pre-set flow delivery. However, the slack in the system was too large or the maximum FASTSTART volume too small to initiate fluid flow during the first 10 seconds (5 of 12 measurements) or to achieve steady state flow rate within 90 seconds (10 of 12 measurements).

After priming the infusion system, clinically acceptable start-up times T_2 were recorded in all three infusion syringe brands without FASTSTART, and in our experience this is one of the beneficial features of the type of pump tested. The differences between the three syringe brands regarding start-up times T_2 and first-minute effusates were related to the differing syringe compliances reported earlier [6]. The higher the compliance, the longer the start-up times and the smaller the first-minute effusates. This means that after optimum positioning of the syringe in the pump, as well as in transmission, syringe compliance is an important factor in delayed start-up

which cannot be overcome by the priming manoeuvre.

With FASTSTART and prior priming there was a reduction of some 50% in the mean time to pre-set flow rate in all syringe brands. However, wide differences were observed within the "no FASTSTART" and "FASTSTART" groups. A blocked syringe plunger may have mimicked an optimally placed, primed syringe or plunger pressure above the FASTSTART threshold, so that FASTSTART was not activated for each measurement [7]. In consequence, the initial pressure may have been used to mobilise the blocked plunger, resulting in delayed fluid delivery and hence a wide range of recorded times.

The measured amounts of first-minute effusate did not exceed the twofold volume normally delivered for one minute when FASTSTART was used. Thus FASTSTART can be considered safe even when highly concentrated, potent drugs are used. The fact that no statistically significant differences were recorded, whether or not FASTSTART was used in the primed syringe, indicated that FASTSTART was a highly sophisticated mechanism which prevented inadvertent fluid or drug boluses in an optimally primed syringe.

Our data clearly demonstrate that mean start-up times of the primed CODAN syringe without FASTSTART were equal to those of the primed IVAC syringe with FASTSTART and even superior to those of the primed Fresenius syringe with FASTSTART. It is suggested that smaller syringes with smaller compliance and higher plunger speed ($mm.h^{-1}$) may further shorten start-up times [4, 8, 9].

However, this study investigated only isolated fluid delivery from the infusion line tip of a syringe pump. It must be borne in mind that in clinical practice other factors can cause delay in start-up of fluid or drug delivery into the venous circulation. Delay caused by the distance from the stopcock to the catheter tip can be effectively reduced by a so-called catheter priming procedure (for example, flow rate 33 $ml.h^{-1}$ for 30 seconds, depending on the internal catheter volume) or by a carrier infusion. Furthermore, backflow of fluid from the stopcock into an infusion syringe pump that is in a lower position can occur when the stopcock is opened, and this delays drug delivery to the central venous catheter. Third, connection of the infusion line to a fluid-filled stopcock port can elevate the pressure in the syringe pump system, resulting in a small bolus when the stopcock is opened. In view of these contributing factors, differences between syringe brands and further improvements in start-up performance become less important.

Our data indicate that the FASTSTART procedure effectively and safely reduces start-up times in syringe pump infusion systems. However, priming the syringe proved to be the most effective manoeuvre; the FASTSTART system could not achieve the same performance in terms of a rapid start to stable drug delivery.

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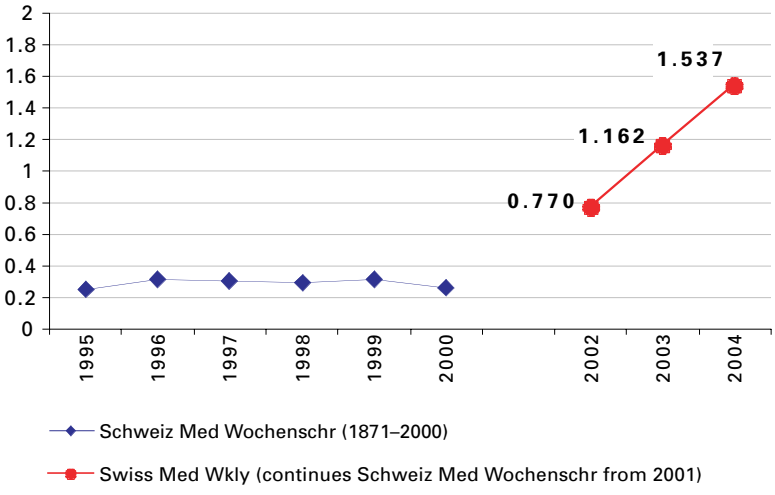

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