2016

Achieving Improved Patient Care with DripAssist™:

More Accuracy in Less Time

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Introduction

Clinician time versus accuracy of results

Infusion of intravenous (IV) fluids is among the most common procedures done in healthcare settings worldwide. However, without the aid of costly and complicated infusion pumps, the ubiquitous infusion procedure can pose dangers for patients. Research has shown that 75% of all gravity infusions set at rates too high or low for patient safety.[1] Research consensus shows that gravity infusions are “an area of risk for patient safety [with] important consequences on nursing workload as they are required to correct the inaccuracies in flow-rate.”[2]

In this paper we will demonstrate how the DripAssist saves care provider time while also improving infusion accuracy and patient safety. We will consider various approaches to gravity infusion and analyze each in terms of **provider time versus delivered infusion accuracy**. As we will see, accuracy and provider time investments interact directly, and the DripAssist device has the power to significantly shape that interaction for the better.

Figure 1. The DripAssist device

[1] Rooker, Jemma C; Gorard, David A, Errors of intravenous fluid infusion rates in medical inpatients, Clinical Medicine Vol 7 No 5 October 2007

[2] Bissett, IP; Brandt, TP; Windsor, JA; Survey of Intravenous Fluid Therapies and Accuracy of Gravity-fed Infusions in a Teaching Hospital, Samoa Medical Journal, 2010, Vol. 2, Issue 2.

Characterizing accuracy in gravity infusion

IV fluid preparations are generally prescribed using a combination of flow rate and total volume, e.g., 125 milliliters of fluid per hour infused over a two-hour period. This is to assure that the total amount of infusate is safely delivered at the rate needed for its particular therapeutic use. Therefore, an accurate infusion will deliver a specific volume of fluid at a specific rate.

In administering gravity infusions, the task of nursing staff is to assure accuracy by maintaining a constant infusion rate over a calculated time period. Maintaining a constant infusion rate may seem straightforward at first, but in reality all gravity infusions experience rate changes during the course of the infusion; both at the drop-to-drop level and longer-term changes over the course of the infusion.

All gravity infusions experience rate changes during the course of the infusion.

Through our experimental setup, we can discover the sources of systemic and random error in gravity infusions, and graphically illustrate the accuracy of various techniques.

Experimental Setup

In order to collect flow rate data, we used a bench setup as follows:

An off-the-shelf drip set was attached to a standard 1-liter IV bag hung on an IV stand. Standard tap water was used in all tests. This was assumed to be an adequate comparison due to the negligible difference between tap water and saline solution viscosities. An empty plastic bucket was used to collect the dispensed fluid. The bucket was placed on an electronic scale (Ohaus NV2101) with measurement resolution of 0.01g and accuracy of ±0.2g. During the infusion, the scale continuously logged accumulated weight in the bucket at a rate of one sample per second providing a cumulative measure of volume and, by taking the first derivative, a measure of flow rate.

To investigate the relationship between invested clinician time and achieved infusion accuracy, we performed several trials, collecting data for each as presented below.

Trials

Unmonitored Gravity Infusion

For this baseline experiment, we performed a two-hour infusion at a prescribed rate of 125 mL/hr. After setting the initial rate via manual counting, no further interventions were performed; the infusion was allowed to run its course naturally for two hours.

To set the rate, a Shift Labs employee used hand-counting (14 drops over 20 seconds) to set a rate of 125 mL/hr using a drip set with a drip factor of 20 drops/mL.

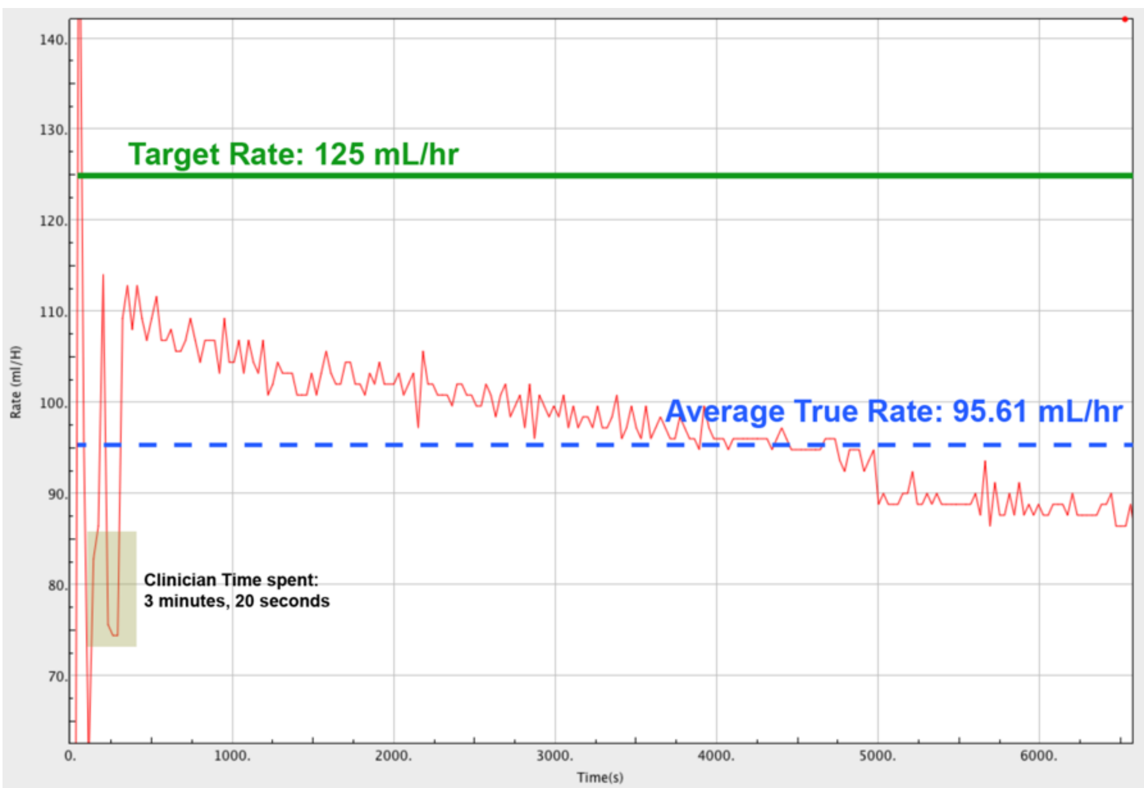

Figure 2. Infusion rate variation in a typical gravity infusion.

Clinician time investment: 3 minutes, 20 seconds. Infusion error rate: 23.5%

Figure 2 above is illustrative of the rate and volume inaccuracy often seen in an unassisted gravity infusion. The thin blue line shows the average infusion rate, while the thick green line shows the prescribed infusion rate of 125 mL/hr.

There are several things to note in this figure.

Figure 3. Adjusting infusion flow rate with a roller clamp

The first, and arguably most crucial thing to note, is that the actual delivery rate at the beginning of the infusion, as measured by the weight scale, was significantly lower than the target 125 mL/hr rate the operator set via hand-counting calculations. After several minutes of adjusting the rate and re-counting via a stopwatch, the operator settled upon a rate which was closer to 115 mL/hr, approximately 8% below the prescribed rate.

This example illustrates an important issue in gravity infusion monitoring. Using a drip set with a factor of 20 drops/mL and a 20-second counting period, the difference between 115 mL/hr and 125 mL/hr is a single counted drop. These “off-by-one” errors are almost inevitable when hand-counting, as a drop may fall just at the beginning or end of the timing period, at which point it is unclear whether it should be counted or not.

By the end of the two-hour period, the actual measured volume of fluid dispensed was only 194 mL, an error of almost 24%.

The second major point illustrated by Figure 2 is that **gravity drip rate, once initially set, does not stay the same through the course of an infusion.** As seen in the figure above, the infusion rate which begins around 115 mL/hr has fallen to approximately 87 mL/hr by the time the two-hour infusion is completed. In the case of an IV bag which is not disturbed and in which the height relationship between the bag and the outlet does not change, infusion rates tend to fall significantly across the course of an infusion.

As the height difference from the top of the fluid level in the IV bag to the venipuncture site changes (e.g. as the fluid level in the IV bag lowers, the IV stand is repositioned or a patient changes positions), the flow rate will change. This will cause a significant error in overall flow rate unless the operator notes each change in height and follows up with constant, consistent hand-counting and roller clamp adjustment.

By the end of the two-hour period referred to in Figure 2, the actual measured volume of fluid dispensed was only 194 mL, an error of almost 24% when compared to the expected volume of 250 mL assumed through the hand-counted rate. Due to the low initial set point and the falling rate throughout the infusion process, the actual average rate was 95.6 mL/hr--about 24% below the prescribed 125 mL/hr expected trough hand-counting, therefore resulting in our observed volume error.

In summary, this infusion took 3 minutes and 20 seconds of provider time, but delivered an infusion that was almost 24% under the prescribed average rate and, thus, total volume infused. This is consistent with research showing the inaccuracies of gravity infusion administration.[3]

In the spirit of improving infusion accuracy, we now consider an approach of periodically checking the infusion rate. While this does not directly address the inherent inaccuracy of counting drops

[3] Carleton, Bruce C.; Cipolle, Robert J.; Larson, Stella D.; Canafax, Daniel M.; Method of evaluating drip-rate accuracy of intravenous flow-regulating devices. American Journal of Health-System Pharmacy, Nov 1991, Vol 48.

(and the off-by-one errors that can easily occur), checking the infusion rate by repeating the hand-counting operation can correct for the slow drift in rate which occurs as the bag empties.

Hand Counting with “Checkups”

An easy way to improve the accuracy of our gravity infusion is to periodically check the infusion rate using hand-counting and adjusting the roller clamp as needed. Thus, by investing more clinician time per infusion, we can improve overall infusion accuracy.

In the following trial, we used the same bag height, drip set, and infusion rate of 125 mL/hr, but checked the infusion rate every half hour by counting drops over a 20-second period, resetting the rate as needed.

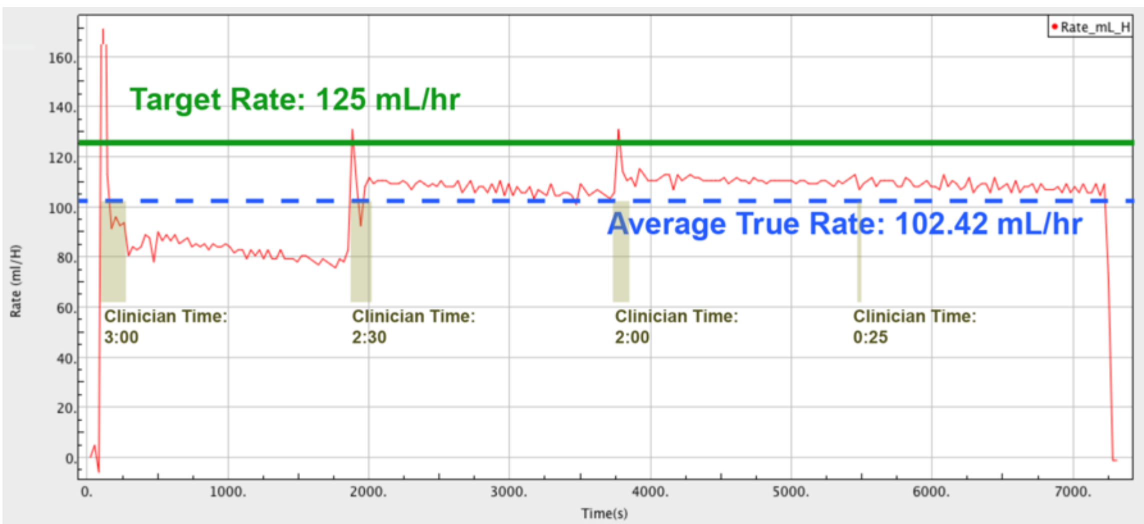

Figure 4. Gravity infusion with hand-counting—rate checking every half-hour.

Clinician time investment: 7 minutes, 55 seconds. Infusion rate error: 18.1%

Compared to the trial in Figure 2 the benefits of periodically checking an infusion are immediately obvious. Even though the initial set rate was lower than the target rate, the follow-up checks provided an opportunity to correct the rate periodically as it continued to drift downward, yielding an overall improvement in accuracy.

There are two major points to note in Figure 4: First, even with interventions every half-hour, all chosen rates were measured to be below the prescribed rate of 125 mL/hr. Again, a simple “off-by-one” error in choosing to count or not count a single drop over the course of a 20-second measurement can cause this much error in drip rate.

The second point is of equal significance: These frequent interventions to check and reset the rate cost significant provider time. In this case, the operator spent a total of 7 minutes, 55 seconds interacting with the drip set – and still delivered an infusion that averaged **18% below the prescribed rate / total volume.**

So we now see the two-pronged problem of delivering accurate gravity infusions using hand-counting: it is difficult to accurately measure the flow rate through manual counting, and increased infusion accuracy can only be achieved through significant time expenditure, both at the beginning of the infusion and periodically throughout its course.

The DripAssist Infusion Rate Monitor was developed to address this issue. In the next section, we will see how the DripAssist fundamentally changes the accuracy versus time tradeoffs for gravity infusion.

DripAssist

The DripAssist was designed to improve the accuracy of infusions while reducing provider time spent per patient. By providing a highly accurate, “glanceable” measure of flow rate without hand-counting, both the initial rate setting and subsequent flow rate checkups can be achieved in far less time. Furthermore, the rate alarm can alert clinicians to flow rate changes which demand their immediate attention.

Because the DripAssist does not control the infusion rate itself, it still requires clinician time to check and adjust the flow rate as needed. However, there are three significant differences to the clinician experience when using DripAssist:

1. The DripAssist is extremely accurate at measuring drip rates, with less than 1% error in measured drop rate and estimated flow rate.
2. Using DripAssist, the current flow rate can be determined at a glance, instead of counting drops over a period. This yields significant time savings over the course of an entire infusion.
3. With the DripAssist’s rate alarm activated, the device will sound an alarm if the rate changes by more than 13%. Thus, the clinician is alerted immediately if a significant rate change occurs.

To see how these product features impact a typical infusion, we performed another trial using the DripAssist to provide infusion monitoring in conjunction with a standard drip set and roller clamp. The chosen target rate was, again, 125 mL/hr over a two-hour period.

As in the previous trial, our primary interest is in comparing the investment of clinician time in managing this infusion versus the rate accuracy achieved by this method. To this end, we adopted the following protocol for using the DripAssist:

- Set the initial rate using the DripAssist, and activate the rate alarm.
- Check the rate every half hour, adjusting as needed (identical to the hand-counting trials).
- Additionally, adjust the rate as needed whenever the DripAssist's rate alarm sounds.
- When adjusting the rate, operators were instructed to err on the high side of the target rate while staying within the stated alarm bounds. With the DripAssist providing an exact rate measure, this allowed operators to counteract the natural rate decrease of an emptying bag, while staying within a safe margin of the prescribed rate.

The results of this trial are shown in the following figure:

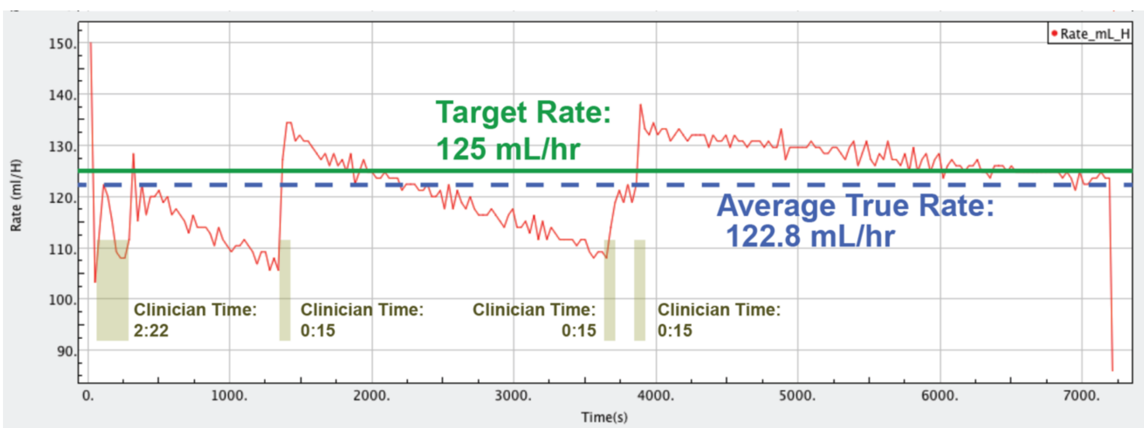

Figure 5. Using the DripAssist device to provide rate monitoring.

Clinician time investment: 2 minutes, 57 seconds. Infusion rate error: 1.7%

In Figure 5, we see a direct illustration of the DripAssist device's power to provide more accurate infusion with less clinician time. To understand the graph, let's consider these statements one at a time:

Infusion accuracy

When using DripAssist, the actual rate is controlled through the same type of roller clamp used in hand-counting; hence, we see the same pattern of rates falling over time. However, the increased measurement accuracy and continuous infusion monitoring of the DripAssist gives us two key advantages. Firstly, by measuring drop rate to within 1% accuracy, the DripAssist allows for an initial rate setting at a higher level of precision than can be achieved with hand-counting. Then, after the initial rate has been set and “rate sagging” sets in, the DripAssist’s alarm alerts the clinician to significant change. Rate adjustment operations are straightforward and accurate – and furthermore, the accuracy allows the clinician to actually set the rate a bit higher than nominal (within the bounds of sound clinical judgment). This allows the clinician to “make up for lost time” by running the drip faster at first, knowing that the rate will eventually slow down.

This technique of “aiming high” is made easy by the DripAssist’s direct readout of current flow rate. By comparison, achieving the same strategy while hand-counting would require calculation of multiple target drip rates, and a fair amount of pencil and paper math to ensure that an appropriate safety margin was maintained.

Reduced Clinician Time Investment

As we’ve seen, maintaining acceptable accuracy with any gravity infusion protocol requires periodic monitoring and adjustment of the infusion rate. With DripAssist, the current flow rate is “glanceable” and can be ascertained immediately by viewing the device’s screen. By contrast, the current flow rate of a traditional gravity drip requires at least 15-20 seconds of measurement, and much longer if a rate correction must be made, often requiring multiple iterations of hand-counting and adjustment. Over the course of a multiple-hour infusion, this adds up significantly. The 2-hour long hand-counting protocol of Figure 4 required almost 8 minutes of clinician time, while the 2-hour long protocol using DripAssist required just 2 minutes and 57 seconds.

Note that the DripAssist doesn’t change the basic *nature* of gravity infusion and the tendency for infusion rates to change over time. Indeed, both trials involved multiple rate adjustments over the course of the infusion. However, the DripAssist device significantly reduced the time required for each rate adjustment, while delivering higher overall accuracy across the course of the infusion (1.7% versus 18.1% error).

Conclusions

Results Summary

For each of the three protocols previously discussed, multiple trials were conducted to establish a baseline for how much variation occurred from test run to run. The results of each set of trials is summarized below.

Unmonitored hand counting

In this group of trials, a nominal rate of 125 mL/hr was set via hand counting and then the drip was left unmonitored for the remainder of the two-hour infusion.

Table 1. Results summary for hand-counting with no monitoring or checkups

Trial	Clinician Time Spent During Infusion	Average Infusion Rate	Magnitude of Infusion Error
A	3:20	95.61	-23.5%
B	2:50	81.73	-34.6%
Averages	**3.05**	**88.67**	**-29.1**

As can be seen from these results, there is a potential for significant rate error in unmonitored gravity infusion.

Hand counting with 30-minute checkup interval

In this group of trials, a nominal rate of 125 mL/hr was set via hand counting and then monitored every half hour to check and adjust the rate as necessary.

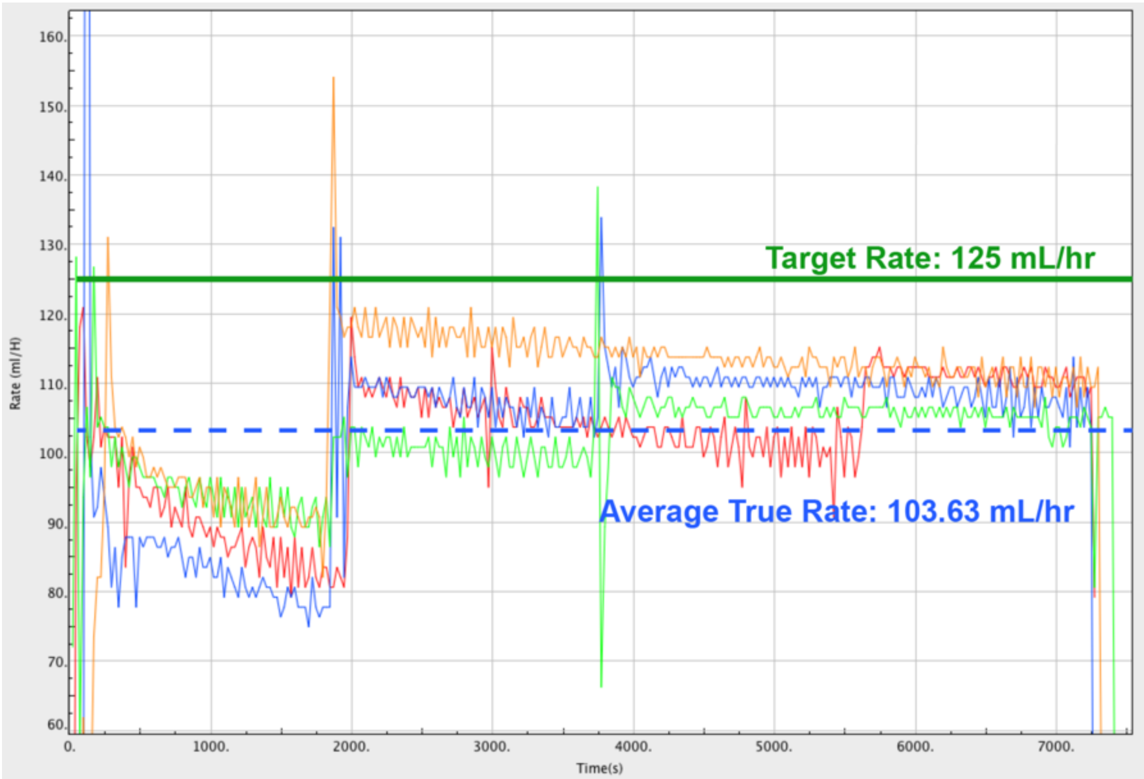

Figure 6. Four trials with hand-counting, rate checks, and adjustments every 30 minutes.

Table 2. Results summary for hand counting with 30-minute checkups

Trial	Clinician Time Spent During Infusion	Average Infusion Rate	Magnitude of Infusion Error
C	7:55	102.42	18.1%
D	7:20	101.78	18.6%
E	8:15	101.53	18.8%
F	**8:49**	**108.78**	**13.0%**
Averages	**8:04**	**103.63**	**17.1%**

As can be seen in the data above, periodic checks and adjustments of the roller clamp can increase the accuracy of gravity infusion when compared to an unmonitored infusion, but the gross inaccuracy of hand-counting itself leads to a large infusion error, despite a time investment averaging more than 8 minutes over a two-hour period.

DripAssist with 30-minute checkup interval, rate monitor alarm

We performed a total of 6 trials using the DripAssist as an infusion rate monitor. All trials used a 125 mL/hr nominal rate. The DripAssist was used to set initial flow rate, and the rate alarm monitor was set to alert to flow rate changes of more than 13%. Checks and rate adjustments were performed every 30 minutes or when the alarm sounded.

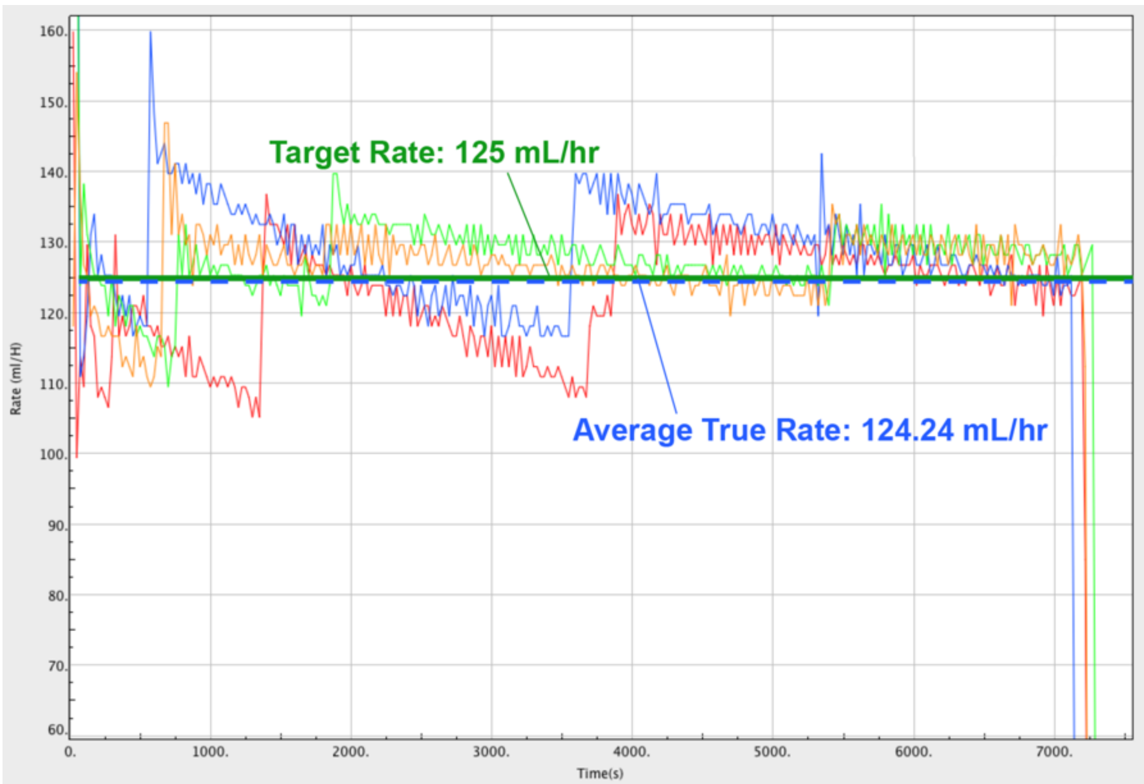

Figure 7. Six trials using DripAssist with checks every 30 minutes or when alarm sounded

Table 3. Results summary for DripAssist-aided infusions. Checks every 30 minutes or when alarm sounded

Trial	Clinician Time Spent During Infusion	Average Infusion Rate	Magnitude of Infusion Error
G	5:21	120.41	3.7%
H	3:45	117.42	6.1%
I	2:57	122.83	1.7%
J	3:35	129.4	3.5%
K	3:23	128.41	2.7%
L	5:13	126.99	1.6%
Mean	**4:02**	**124.24**	**3.2%**

Here, we see the power of the DripAssist device to reduce provider time investment while substantially improving accuracy. Over the course of these six trials, the operator using the DripAssist device spent almost exactly half the time needed to manipulate the roller clamp as the operator using hand-counting. In addition, the DripAssist trials averaged an infusion rate error of just 3.2% compared to the hand-counting trials' average error of 17.1%.

Conclusion

Through this exploration of various protocols for administering gravity infusions, we have demonstrated some key points which can inform any discussion about infusion protocols in your care setting:

Gravity infusion rates change over the course of an infusion.

A number of factors influence the rate of gravity infusions, including, but not limited to: the bag height, position and blood pressure of the patient, viscosity of the liquid being administered, and amount of fluid remaining in the bag itself.

An unmonitored gravity infusion cannot be relied upon to drip indefinitely at a uniform rate.

Accuracy can be achieved through additional provider time investment.

In our trials, we showed how periodically checking and adjusting the IV flow rate yields a more accurate infusion overall. The question then becomes: how much provider time is needed to substantially improve infusion accuracy? We have shown that using traditional hand-counting and performing periodic rate checks quickly becomes very time-consuming – and that, due to the inherent inaccuracy of hand-counting, it still doesn't yield an accurate infusion.

One way of getting a more accurate hand-counted rate is to count drops for a longer period of time – say, counting drops over the course of an entire minute instead of a 20 second period. However, this will clearly take additional provider time in exchange for the greater accuracy.

The DripAssist device substantially improves accuracy while reducing provider time per patient.

Using the DripAssist device to administer gravity infusion brought the average infusion error down from 17.1%, in the case of a periodically monitored hand-counted infusion, to just 1.7% - while simultaneously cutting in half the provider time burden per patient. This represents both a substantial improvement in operational efficiency and a greatly increased standard of care for patients.

DripAssist is the only gravity infusion protocol which provides continuous monitoring.

One final point to consider is the following: with traditional hand-counted gravity infusions, the drip chamber is only being observed when the provider is in the patient's room. If a provider checks the infusion every 30 minutes, there is 30 minutes of time where a bumped or dislodged roller clamp could be causing the IV to free-flow or for flow to stop completely.

DripAssist changes this equation completely. By nature, when the rate alarm is enabled, the device is continuously monitoring the drip rate, immediately alerting the provider it varies by more than 13% from the set point. No matter what the checkup interval, with a DripAssist device in use, no line can stop or free-flow for more than a few seconds without an immediate audiovisual alarm.

On top of the significant improvements to accuracy and reduced provider time to manage each drip, this continuous monitoring presents a clear advantage for patient safety.