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Intravenous (IV) Drip Rate Controlling and Monitoring for Risk-Free IV Delivery

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***Abstract*— Intravenous (IV) drip mode is one of the most used modes for drug delivery. It delivers the drug into the blood circulation directly. It is widely used because of its advantages like its affordability, safety, effectiveness and speed of delivery of pharmacological substances and other fluids. Albeit its many advantages, a few complications could arise in its usage if it is not administered properly. In this paper we discuss the advantages and risks of IV drip set, the importance IV drip rate, existing infusion pumps and their drawbacks, attempts made to overcome the drawbacks of infusion pumps and finally the need for next generation IV drip set which can not only monitor but also control the drip set.**

Keywords—Intravenous (IV) Drip Monitoring system; IV drip set; Drip Rate; Fluid administration; Infusion pump; Gravity drip; Backflow; Over infusion; Under infusion;

I. INTRODUCTION

One of the main activities in clinical medicine is the treatment of diseases by pharmacology. This is done by supervising the medication by various methods like oral, intra-arterial, intramuscular, subcutaneous and intravenous (IV) routes. IV therapy is the administration of fluids (and other medications) into a vein directly. Intravenous (IV) route is the fastest way of delivering medications and replacing fluid throughout the body. IV Drip/Blood Meter is extensively used in clinical and home care settings to treat conditions such as severe fluid loss, pneumonia, dehydration, electrolyte imbalance, anemia, high fever, etc. The main perk of IV is that the fluids can be delivered in the fastest mode throughout the body and immediate effect of the medication can be achieved. Also, a few medications cannot be given by any other method other than IV. In IV therapy, the medication is 100% bioavailable and it is relatively inexpensive. Though IV drip is an effective tool yet many complications can arise if it is not done right. Numerous complications like Biochemical disturbance, Haemodilution, Renal impairment, Hypersensitivity, etc can occur as a result of fluid therapy. Hence monitoring and controlling the drip rate of IV fluid becomes very crucial because any slightest change in the drip rate of IV fluid might cause severe side effects.

II. REVIEW SURVEY

According to the stake-holder's feedback the following conclusions can be drawn which are represented by the following figures: In any hospital, due to fewer nurses, their job could be simplified to a great extent by IV monitoring and controlling device. Blood back flow can be avoided; by the help of monitoring device. This device would make the nurses' job easier up to 81% also, it would be easier to know the reservoir level for injecting additional drugs to the drip bottle.

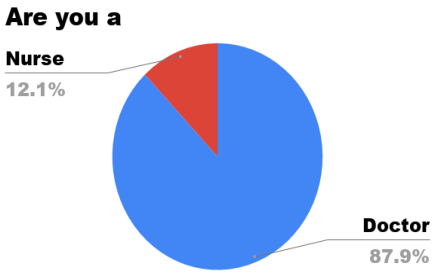

Fig. 1. Percentage of doctors and nurses

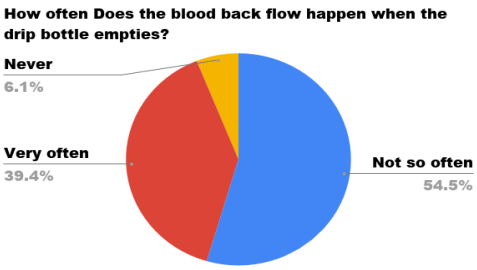

Fig.2. Chances of blood back flow

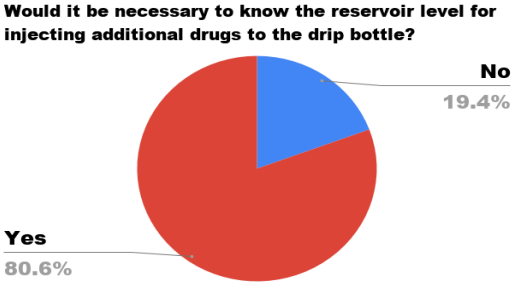

Fig.3. Reservoir level for injecting additional drugs

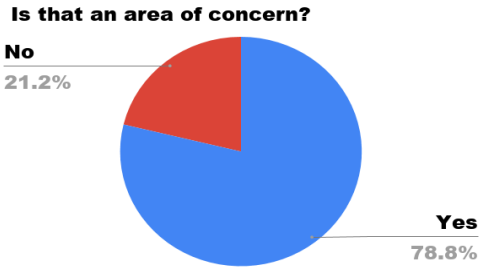

Fig.4. Area of concern

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Stake-holder feedback on the major issues while using IV drip set gives the following statistics. As per our survey, there is 70.60% need to keep track of the IV fluid that is being administered; the accuracy of the drip rate is 44.10% whereas clotting at sight of administration is 55.90% and blood backflow is 38.30%

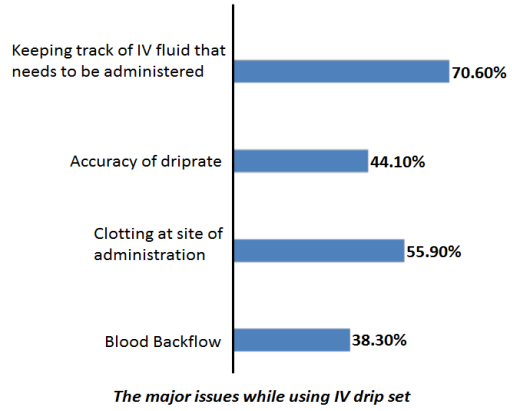

Fig.5. Major issues while using drip set

III. DRIP SET: ITS ADVANTAGES AND RISKS

There are range of medical conditions, which require intravenous therapy including severe fluid loss (E.g.: due to burns), dehydration, pneumonia, electrolyte imbalance, high fever, etc. Substances that are usually administered through intra venous route includes: buffer solutions, nutrition, blood based products, volume expanders, blood substitutes, etc. There are some fluids that are often routed by gravity feed through a type of constriction, which allows to control the fluid being administered. Almost all the clinical intravenous fluid administration set will include a fluid reservoir, and a capillary tube of fixed diameter for fluid to pass through, called a drip chamber, and the drops formed will drip from tube into the chamber when they reach certain volume. To produce a fixed number of drops per unit time, the clinician adjusts the flow rate.

Here, the driving pressure is the difference between the hydrostatic pressure generated by the column of liquid in the intravenous set and the venous pressure. Since, the latter is typically around 4-8mm of Hg, the driving pressure is approximated to be the column of liquid. The reservoir is usually adjusted 60-100cm above the patient. Intra-arterial injection is impractical as it requires raising the reservoir to around 2 mts.

The drop factor (also called the drip factor) of a drip set is the number of drops which make one ml of solution. It is drip set specific.

Now, drip sets are available in various sizes and shapes and with a variety of drop factors. But, the most widely used are the micro drip and macro drip.

Macro drip (regular drip) takes 10, 15 or 20 drops to deliver one ml of fluid. They are used to infuse greater volumes or infuse fluids quickly. Micro drip tubing takes 60 drops to deliver one ml of fluid. It is used to infuse smaller volumes or very precise amounts of fluid. Intra venous fluids are to be given at a specific rate, neither too fast nor too slow. The specific rate may be measured in drops/min, ml/min, ml/hr, liter/hr. and others.

A. *Advantages of IV drip set:*

- It is relatively inexpensive
- Best method if patient cannot tolerate drugs by oral or any other route
- Immediate therapeutic effects is achieved due to rapid delivery of fluid to target sites
- Some substances cause pain and irritation when given subcutaneously or intra-muscularly
- A few drugs can only be absorbed by Intravenous route
- In intravenous therapy, the bioavailability of medication is 100%

B. *Risks involved in IV therapy:*

- Medication error
- Air embolism
- Particulate contamination
- Chemical contamination
- Sharps injury
- Drug incompatibility
- Microbiological contamination

IV. IMPORTANCE OF IV DRIP RATE

The following are the reasons why drip rate should be monitored:

The drip rate set by nurse can change due to various reasons. A few are listed below.

- Composition, concentration, viscosity of fluid in the reservoir
- Changes in patient's position
- Height of reservoir above the patient
- Occlusion of the device e.g. Due to an inflated BP Cuff
- In addition, the variation in the cross section of the patients vein can affect the flow rate
- Reduction in pressure as the reservoir volume decreases will decrease the flow rate
- Patients occasionally adjust the roller clamp or other parts of the delivery system

Medication error may lead to under infusion or over infusion. For some drugs whose therapeutic levels if are close to their toxic limit, then administration of this type of drug might lead to suboptimal therapy or have toxic side effects. Under-infusion is the situation where less fluid than intended is delivered to the patient. Under-infusion may result in following consequences: Dehydration, Metabolic disturbances, a delay in response to the medication. Over infusion is a situation where more fluid than the intended is delivered to the patient. Consequences of over infusion include: Metabolic disturbances, Shortness of breath, High blood pressure, Electrolyte imbalance, Speed shock, etc. Over hydration must be prevented particularly for patients who require small volumes of fluid. Over hydration can lead to edema and death.

The problem of flow control of drips affects the following client groups: infants, children, Geriatric, organ impairment or organ failure patients, patients with impaired cardio vascular status, patients with major sepsis, post operated patients. India and many developing countries have the hospitals massively overcrowded and under staffed. Uniform size of bags adds to

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the problem. One liter and 500ml is most common in the developing world. But these bags are too large for client groups mentioned earlier, who need only a part of that fluid. Drip rate varies with variation in different parameters like: for different IV fluids, for the time duration within which an amount of fluid should be given, for different age groups, for different diseases, for micro drip or macro drip, etc.

For example, the variation in the drip rate for daily fluid requirement in pediatrics is as tabulated below:

TABLE I. Drip rate for daily fluid requirement in pediatrics

Weight in kg	Drip rate in ml/hr	Daily volume in ml
3.5 to 5	15 to 21	350 to 500
5 to 25	21 to 67	500 to 1600
25 to 50	67 to 88	1600 to 2100
50 to 120	88 to 100	2100 to 2400
120 to 160	100	2400
160 to 200	100	2400

In a similar way monitoring the drip rate becomes very crucial for any given disease. Variation in the drip rate would not only have severe consequences but could also lead to death in critical cases.

V. DRAWBACKS OF THE CURRENT INFUSION PUMP

Fig.6. Infusion pump

In resource rich settings, Infusion pumps are used to provide IV therapy. But they have few drawbacks like:

- They are complex systems which are hard to setup and maintain.
- They are expensive.
- They are less portable.
- They require specific infusion sets.
- Constant electrical power is required to operate them.
- They are bulky.

VI. ATTEMPTS MADE TO OVERCOME THE DRAWBACKS

Attempts were made to overcome the challenges with adaptation of IV drips. A few are discussed below.

The traditional method of infusion were replaced by using embedded system technology, a system for detecting the variations in light transmission between a LED and a photodiode placed around IV drip chamber to monitor IV drops. This system was designed to run with a battery but it does not have a regulator to save battery power. Another IV drip monitor based on optical sensor called Accuflow was commercialized and the results of its evaluation were reported by Shroff et al. The device displays the flow rate and has alarms which operate when the rate deviates from pre-set value.

Other companies like Shift-labs tried to develop compact IV drip monitor Drip Assist, which was also based on optical sensing. Vignali et al reported on design of an IV stand where an alarm for low fluid level is also proposed. They have used combination of LED and phototransistor for monitoring the drip rate to provide alarm. Various research groups have used methods other than optical sensing to monitor IV drips. These include capacitive sensing, piezo electric sensing, ultrasonic sensing and also Microwave time domain reflectometry sensor which is applied to side of the drip bottle/bag.

Thus, existing approaches are limited to monitoring of drip rate. While the optical sensing of drips is promising, other approaches have many disadvantages like they are complex, not reliable, and not affordable and are not in the market yet or not being use widely.

VII. EXISTING PRODUCTS

Few drip rate monitoring devices already exist like DripAssist, Drip-Alert, AutoClamp, etc which are accurate and stable fluid infusion devices. These devices monitor the drip rate and alarms to indicate if there is any deviation from the pre-set value of drip rate. A few of the existing devices are mentioned in detail below.

Fig.7. DripAssist®: Infusion Rate Monitor

DripAssist Infusion Rate Monitor device is known to deliver precise and fast IV infusion. It can manage and monitor IV drip without pump, easily and can use gravity infusion. There is no need for the following parameters like maintenance, calibration or asset tracking. It is a small device and has appreciable versatility and portability. The drip count is accurate and reliable for any fluid or medication.

Fig.8. AutoClamp

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In Auto Clamp® the medication is administrated to patient with precision and safety. The rate of flow of the fluid is detected when the drops pass through the infrared sensing device. At the lower compartment of the drip chamber, a controller enables to set the desired infusion value to adjust the flow rate. No other tubes are used other than the tubing set for AutoClamp® to get precise readings.

Fig.9. Drip-Alert device

Drip-Alert device is a simple device which alerts by audio and visual alarm if there is any variation in the drip rate or instability or if it deviates from the required drip rate set initially.

Conclusion can be drawn that out of all the existing products that existing approaches are limited to measuring of drip rate.

C. Advantages of drip rate monitoring devices:

1. Accurate and stable fluid infusion
2. Operation is simple
3. Care and time of nurse is minimized
4. Easy to use
5. Audible and visual alarm function

D. Disadvantages of drip rate monitoring devices:

1. High maintenance
2. Specific to a single drip set
3. Bulky
4. Not cost effective
5. It only monitors the drip rate

VII. NEED FOR AN ACCURATE AUTOMATED SYSTEM TO MONITOR IV FLUIDS AND CONTROL AS WELL

It is clear from above mentions that an accurate, automated system to monitor and/or control fluid administration through IV drips which can be applied at home as well as at clinics, under limited resource setting by respective caregivers to prevent associated complications is necessary.

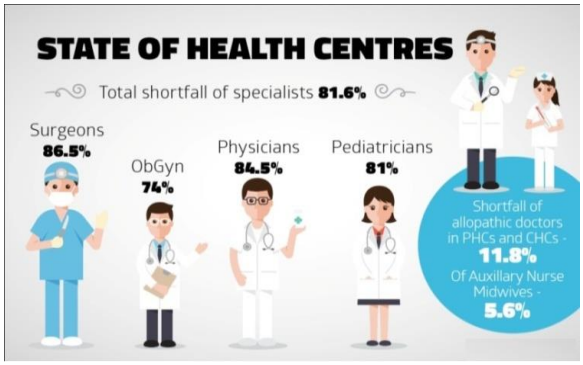

Fig.10. Shortfall of numbers of caregivers

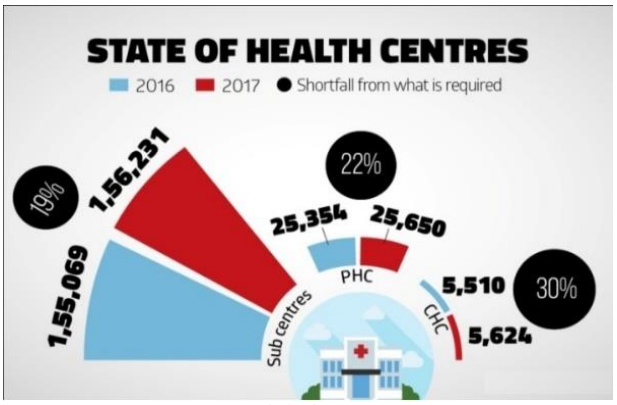

Fig.11. Shortfall of PHCs and CHCs

The above figures (Fig. 10 and Fig. 11) clearly depict the shortfall of the staff in developing countries like India and how vital it is to reduce the burden on doctors and nurses by introducing modern solutions that can be developed by using technology.

IX. CONCLUSION

Not only is the usage of Intravenous (IV) drip very significant and crucial in pharmacological drug delivery but if it is not done right, then it has severe impacts and side effects. IV drip is surely a safe, affordable and effective tool; even then several complications might arise in its usage. Hence administration of the IV fluid should be done very carefully.

Only by tackling the problems encountered in the usage of IV drip, minimizing its complications and improvising its accuracy, we shall be able to provide the required care to the patients. Hence there is need for design and innovation of next generation IV drip set which can not only monitor but also control the drip rate according the requirement. The device should not only be simple to use but also cost effective and affordable to all human strata.

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