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Training Objectives:

- ✓ Knowledge of the factors that affect the flow of an infusion
- ✓ Gain an overview of the way of function of the various infusion techniques
- ✓ Knowledge of the indication and dosage exactitude of the various infusion techniques
- ✓ Comprehension of the effects which the individual technical approaches have got for the user

DOSAGE OF INFUSIONS

This chapter starts describing the factors which determine the necessity of exact dosage as well as those which affect the flow of the infusion. In the following the various infusion techniques are treated – gravity infusion, pressure infusion as well as various kinds of infusion equipment – and information about their function and their areas of application are provided.

9.1 General Considerations

Venous or arterial application of a liquid into the circulatory system always requires a more or less exact dosage. The infusion technique employed determines the accuracy of the dosage. The required dosage accuracy is generally dependent on the patient's status as well as on the type and amount of fluid to be infused, the infusion equipment used and the surrounding conditions.

The flow of the infusion is affected by a range of factors:

- Resistance in the channel of the piercing spike
- Resistance in the tubing and in the connector pieces
- Speed of drop formation
- Constancy of the delivery pressure
- Physical and chemical characteristics of the solution
- Surrounding conditions

Over the years, a **standardised infusion set** (DIN 58362 and following) has been developed (see Illustration 9). It consists of the following elements.

- **Piercing spike:** Depending on the type of container to be used with, the piercing spike is sharp (for rubber stoppers) or rounded and blunt (for bag insertion sites). It contains one channel for fluid and optionally a second channel for venting.
- **Vent** (usually present): Upon opening of a cap or stopper air flows into the container. The vent usually is equipped with a bacterial filter.
- **Drop chamber:** A drop generator is located at the top of the drop chamber, which produces drops of a certain size. The chamber is partially filled with liquid in order to prevent air bubbles from entering the tubing. A particle filter is often located at the bottom outlet of the chamber.
- **Connection tubing:** Usually 150 cm long and made of PVC; for special applications also available in other lengths and materials.
- **Roller clamp:** Regulates the flow rate of infusion by controlled compression of the tubing.
- **Luer fitting:** The Luer fitting guarantees a secure connection to all other products by means of the standardised Luer cone. In the lock version the lock connection is further secured against jerks and pressure by means of a screw thread.
- **Protective cap on the spike:** This prevents damage to the packaging and thus loss of sterility. Sets where caps have fallen off must not be used because of this risk.

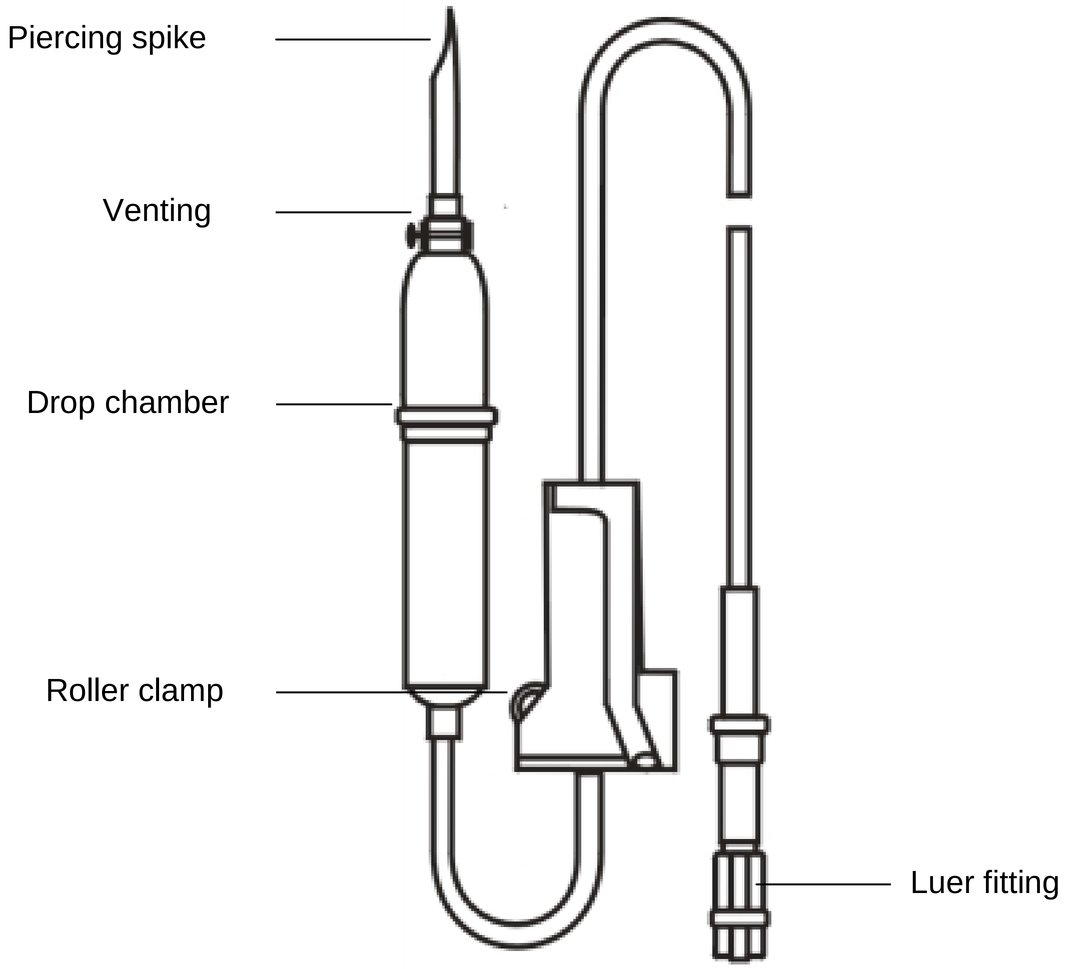

Figure 9: Standardised infusion set

9.2 Gravity Infusion

The technique most frequently used – more than 80 percent of all infusions performed – is the gravity infusion. The accuracy of the dosage and the infusion rate requirements are low for this type of infusion (±50%). The volume supply is dependent on the hydrostatic pressure differential between the patient and the infusion bottle. The rate of fluid supply can only be accelerated through compression of the container or through raising the internal pressure.

Components used for this type of infusion are: infusion container (bottle, bag), infusion or giving set (drop chamber and infusion tubing) as well as the roller clamp.

The rate of the infusion is mainly regulated by means of the roller clamp. The roller clamp is positioned on the infusion tubing of the infusion set in such a way that the lumen of the infusion tubing is compressed from outside. Over time the tubing material gives way to the pressure and the diameter of the tubing lumen decreases resulting in a corresponding decrease of the flow rate (see fig. 10). After a few minutes the roller clamp must be readjusted to achieve the originally set rate of infusion.

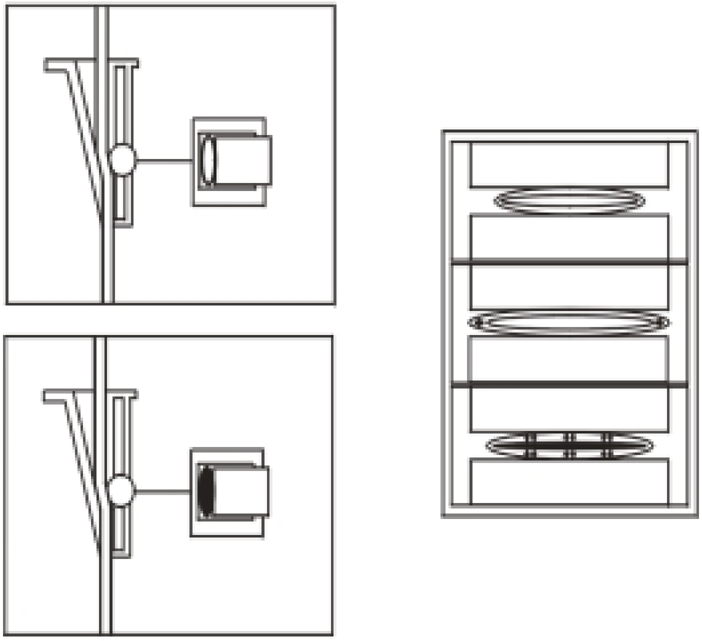

Figure 10: Roller clamp in longitudinal section together with enlarged details showing a cross section view at the point of the roller. As time passes, the tubing material gives way to the pressure, decreasing the diameter of the tubing lumen and the rate of flow.

Important

With gravity infusion, the infusion volume is calculated on the basis of the number of drops per minute. Standard infusion sets are designed in a way that 20 drops equal 1 ml. With the so-called micro-droppers (e.g. Dosifix® - B|BRAUN) 60 drops equal 1 ml.

Tubing-independent flow regulator

This unit replaces the traditional roller clamp. The flow rate is controlled by varying the size of the flow channel. Shifts in the selected drop rate resulting from changes in the tubing are ruled out. Possible settings range from 3 - 200 ml/hour.

These units are used for infusion solutions which are carrier solutions for drugs that need to be administered as constantly as possible.

Product: Exadrop® (see fig. 11)

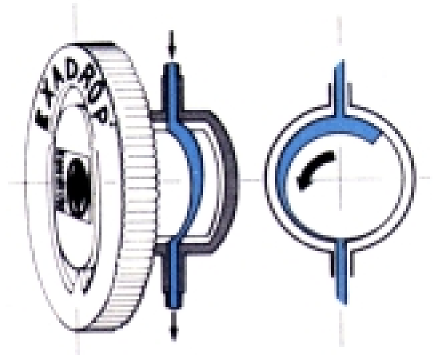

Figure 11: Exadrop® - B|BRAUN. The flow rate is controlled by varying the size of the flow channel in the flow regulator.

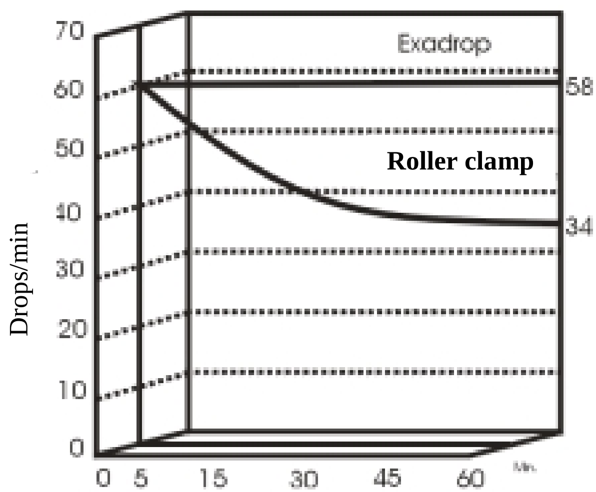

Figure 12: Comparison of the accuracy of a roller clamp and Exadrop® - B|BRAUN. While the number of drops per minute reduces considerably with the roller clamp, it remains relatively constant with Exadrop®

Note

Changes which are not due to the tubing, e. g. changes of the infusion height, patient activities etc. are not affected by the flow regulator.

9.3 Pressure Infusion

When using infusion or transfusion bags, a pressure infusion may be performed. For this purpose a pressure cuff is used which is pumped up with an inflation bulb (as with a blood pressure measurement instrument), thus exerting pressure on the container. A pressure of up to a maximum of 300 mm Hg can be exerted.

9.4 Infusion Equipment

Additional infusion equipment is required when the dosage accuracy should be increased, the rate of infusion should be raised or when a constant rate of delivery during long-term infusions should be achieved. The infusion equipment used should meet certain requirements if the medical and nursing measures are not to pose additional risks for the patient.

The following criteria, established by the Berlin Technical Hospital Service Center, should be fulfilled:

- Requirement-based infusion rate
- Sufficiently exact dosage
- Good sturdiness
- Quick functional readiness
- Simple and safe operation
- Alarm and interruption of infusion in the event of danger (a “must” requirement)
- Mains-independent operation
- Easy cleaning

In accordance with the various tasks to be performed, the required infusion rates extend over a wide range. Rates vary from 1 ml per hour (e.g. keeping open a central venous catheter, infusion for infants) and > 1,000 ml per hour (e.g. forced diuresis, shock therapy) for adult patients. This kind of equipment is therefore mainly unsed in intensive care medicine (since high costs are associated with it).

9.4.1 TYPES OF INFUSION EQUIPMENT

In equipment-supported infusion techniques, distinctions are made between:

- Infusion regulators
- Infusion pumps (e.g. Infusomat® fmS/P - B|BRAUN) and
- Syringe pumps (Perfusor® fm/compact B|BRAUN)

INFUSION REGULATORS

Infusion regulators are electronic medical devices which do not have their own delivery drive. They regulate and monitor the supply of fluid in the flow process. Simply stated, they are mechanised roller clamps. The dosage accuracy is often sufficient for everyday clinical purposes and ranges between ±10 and 20 percent.

INFUSION PUMPS

In contrast to the regulators, infusion pumps have their own delivery drive. Depending on the type of drive, it is to be distinguishes between roller pumps (fig. 13), peristaltic pumps (fig. 14) and piston pumps. Control of infusion pumps can either be drop-based or volume-based. Pumps are comprised of a delivery drive, the control or regulating system and the infusion set. The dosage mainly depends on how the pump is regulated.

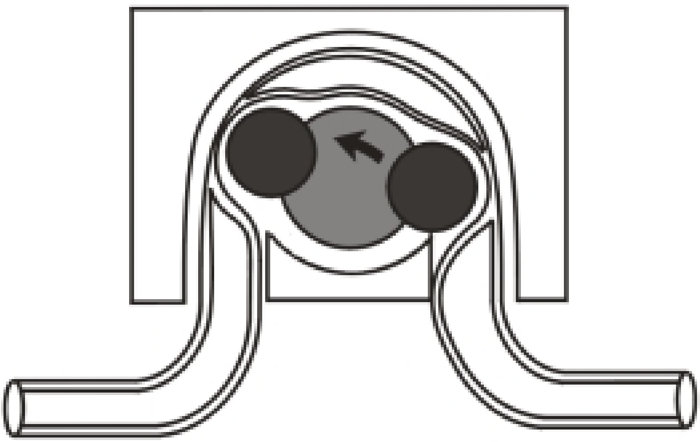

Figure 13: Delivery principle of a roller pump. The rollers bring a set amount of fluid into the tubing which is then transported by help of rotation in the flow direction

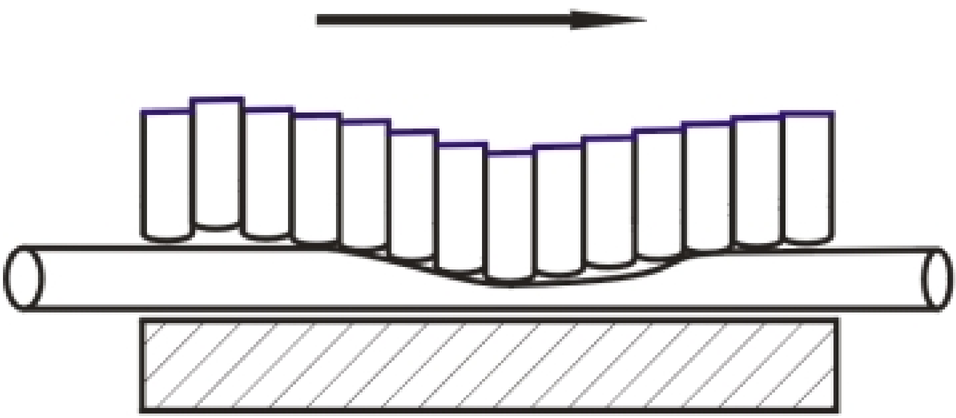

Figure 14: Delivery principle of a peristaltic pump (from MOTZKOW et al.) The successive compression of the tubing by the individual fingers, makes the fluid be advanced forward.

Drop-regulated infusion pumps

The dosage exactitude of these pumps relates to the number of drops (per minute) and depends on the volume of the drops. The drop exactitude is subject to several important conditions such as the viscosity of a solution, the solution's surface tension and the kind of flow behaviour (speed of flow) resulting from these factors. Dosage accuracy is $\pm$10 percent.

Volumetric infusion pumps

With these pumps the dosage accuracy corresponds to the volume that is delivered. The special sets with calibrated precision tubing required for these pumps give a delivery accuracy of ca. $\pm$5 percent.

SYRINGE PUMPS

These are pressure infusion devices which supply the content of one or more syringes simultaneously by means of a precision linear drive.

The dosage accuracy (see above) with these pumps is $\pm$2 percent since a precise syringe volume is delivered through these pumps and all the error sources involved in drop regulation do not apply. This form of infusion is particularly suited for an exact administration of drugs with a dosage rate of 0.1 to 200 ml per hour. Special syringes of 10, 20 and 50/60 ml are commercially available

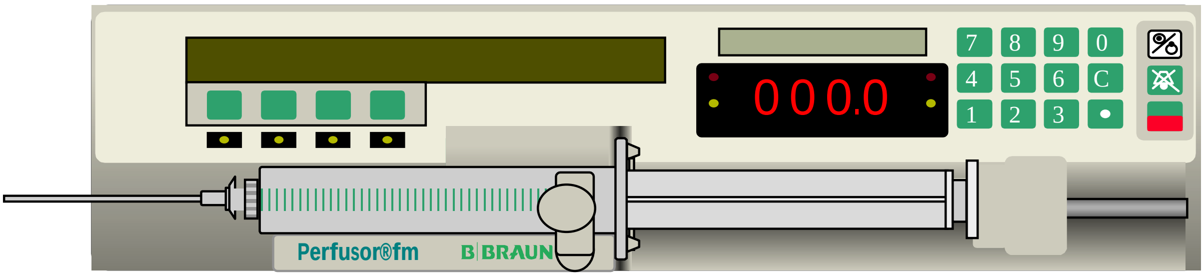

Figure 15: Syringe pump. A defined syringe volume is administered over a specified period of time by help of the action of a motorised drive.

Because infusion pumps work with a maximum pressure of 1 bar, all tubings connected with such pumps need to be pressure resistant for safety reasons.

Note

Exact functioning of infusion pumps is only ensured when appropriate tubings or syringes are used.

The connection of an infusion pump with a gravity infusion (so-called parallel infusion) involves a number of risks and therefore requires particular controls and/or special safety equipment.

9.5 Summary

The degree of accuracy a dosage **must have** depends on the status of the patient, the solution to be infused and other factors. The degree of accuracy a dosage **can have** is determined by the kind of infusion technique that is employed. With regard to these techniques, distinctions are made between gravity infusion, pressure infusion and the use of infusion equipment.

Gravity infusion (as the most frequent infusion technique) entails the disadvantage of a low dosage accuracy. The volume supply depends on the hydrostatic pressure differential between the patient and the infusion container. The rate of infusion is mainly regulated by help of a roller clamp (declining number of drops as time passes) or a tubing-independent flow regulator (relatively constant number of drops over time).

When infusion or transfusion bags are used it is possible to perform a pressure infusion.

Additional infusion equipment is required when the dosage accuracy should be increased, the rate of infusion should be raised or when a constant rate of delivery during long-term infusions should be achieved. In equipment-supported infusion techniques, distinctions are made between infusion regulators (electronic medical devices without an own delivery drive), infusion pumps and syringe pumps. In contrast to the regulators, infusion pumps have their own delivery drives. Depending on the type of drive, there is a distinction between roller pumps, peristaltic pumps and plunger pumps. The accuracy of the dosage mainly depends on how the pumps are regulated. Syringe pumps are pressure infusion devices which administer the content of one or more syringes simultaneously using a precision linear drive. This form of infusion is particularly suited for an exact administration of drugs.

9.6 Comprehension Questions

- Which factors indicate the necessity of the dosage accuracy?
- Which factors affect the flow of infusion?
- What is the dosage accuracy of the various infusion techniques?
- What are the typical sizes of drops?
- Which criteria must be met by infusion equipment?
- Name the different kinds of equipment-supported infusion techniques! What functioning principles are they based upon?
- Explain the functional principle of a syringe pump.
- What must be kept in mind when using infusion pumps?