Variations of drop size in disposable administration sets used for intravenous infusion

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SYNOPSIS The variation of drop size with drip rate has been studied for giving sets made by two major United Kingdom manufacturers. Data are given for the variation using Sodium Chloride Injection (BP), Sodium Chloride and Dextrose Injection (BP) and blood. All sets investigated conformed to BS 2463. A table is provided to enable more accurate delivery of infusion for the three fluids examined.

Continuous intravenous infusion is the common method for introducing comparatively large amounts of fluid into the circulatory system. When infusion is employed to administer drugs intravenously careful control over the dose rate is often necessary. At the start of an infusion the most common procedure for the nurse is the following. A value is assumed for the number of drops per millilitre, the figure generally being approximately 15 for a standard set. The nurse then calculates the drip rate per minute needed to infuse the required volume of liquid in the prescribed number of hours. This procedure assumes that the average drip rate during the infusion remains at the calculated figure. Thus, for a constant drip rate, the dose rate of the infusion is totally dependent on an accurate knowledge of the number of drops per millilitre.

In practice, however, little information is available about the number of drops per millilitre. The British Standard 2463: 1962 *Transfusion Equipment for Medical Use* requires that 'the drip tube shall be so designed that 15-20 drops are equivalent to 1 ml when distilled water is used'. The British Standard requires the manufacturer to mark the drip tube delivery (number of drops of distilled water per millilitre) on the packaging, and this figure is usually 15 drops per ml for a standard giving set. The Standard is under revision at present but it seems unlikely that the relevant clause will be altered.

The present investigation was undertaken to estimate the effect on drop size of different drip rates for a given fluid and of different fluids.

Material

Since it is common practice in many hospitals to use blood administration sets for infusion of fluids other than blood, blood sets were used exclusively. Sets for giving blood are similar to sets for other fluid administration, a major difference being that the former have a filter incorporated in or near the drip chamber. Estimates were made of the range of variation of drop-size both with rate and type of fluid for sets manufactured by two major manufacturers, Avon Medicals (type A11) and Travenol Laboratories (Baxter Division) (type BR10). Since the measurements were carried out the designs of the Avon and Travenol sets have been modified and the types presently available are coded A15 and FK2055 respectively. There has been no change in drip tube dimensions in either case. Fluids were Sodium Chloride Injection (BP) (saline), Sodium Chloride and Dextrose Injection (BP) (saline-dextrose), and blood, contained in plastic packs in each case. Twenty-five sets of each make were investigated for each of the three fluids.

Methods

The giving set and pack of fluid were arranged in the usual way on a stand. An automatic flow regulator was employed to ensure that the drip rate remained steady. The same 'electric-eye' which provided information to the regulator was also used to send a signal, each time a drop fell, into a drop counter which automatically totalled the number of drops passing. The fluid corresponding to a known number of drops was collected in a weighed beaker. Upon

re-weighing the mass per drop could be found. At the lower rates of 20 min⁻¹ the least number of drops collected was 64, while at higher rates of 100 min⁻¹ up to 400 drops were collected. Collections were repeated three times at each rate setting for each administration set. The range of 20-100 min⁻¹, at intervals of 20 min⁻¹, was chosen since experience suggests that these rates are most commonly encountered in general ward use.

The mass per drop was converted to volume per drop using the fluid density measured with a standard hydrometer accurate to 1 part in 500. When the measurements were completed, each drip chamber was cut open and the internal diameter of the drip tube was measured using a microscope. Readings were taken from several scans across a diameter, the tube was rotated, and the procedure repeated.

Results

DROP SIZE v DROP RATE

The data are summarized in the Figure. Comparison of the graphs shows that Avon and Travenol sets give virtually identical results. Error bars shown are indications of the standard deviations calculated for the 25 sets of data whose average result is plotted at each point.

Figure Variation of drop size with drip rate using Avon and Travenol sets and three fluids.

DRIP-TUBE DIAMETERS

Table I shows the results. It must be remembered that the measurements were taken *after* the sets had been used. The first line represents the mean of 25 recorded values of diameters, the second line giving the standard deviation for those 25 readings.

Type of set	Blood	Saline	Saline-Dextrose
Avon			
Mean internal diameter of drip tube (mm)	3.23	3.35	3.35
Standard deviation	0.07	0.04	0.04
Travenol			
Mean internal diameter of drip tube (mm)	3.19	3.27	3.25
Standard deviation	0.07	0.05	0.04

Table I Mean internal diameters of drip tubes following delivery of different fluids

Discussion

The measurements on variation of drop size with rate of formation of drops show that the faster drops are formed the larger they are. This is in accord with experiments reported in many elementary physics texts where the drop weight method of measuring surface tension is discussed. Other important parameters besides rate of formation are surface tension, density, and the effective circumference of the tube where the drops form.

For present purposes, however, it is only necessary to point out that an infusion of saline, say 500 ml, to be given in 500 min (8 hr 20 min) requires a drip rate of 15 drops min⁻¹ (equivalent to 1 ml min⁻¹) if the standard figure quoted on the manufacturer's packaging is used. In practice, one needs something closer to 18 drops min⁻¹ to achieve 1 ml min⁻¹, with the result that a setting of 15 drops min⁻¹ will increase the infusion time by 100 min.

It is important that where equipment depending on drop sensing is used to regulate infusions operating staff should be aware of these drip rate effects otherwise they will feel that the regulator is not functioning correctly. In infusions where no automatic regulator is used, venous pressure and plastic creep effects far outweigh any contribution from drop size variations in producing major fluctuations in infusion rate and hence time for the giving of a required volume (Flack and Whyte, 1974).

In the case of blood it appears that at 60 drops min⁻¹ the manufacturer's figure of 15 drops per ml is a good guide, and the variation over the range examined amounts to only about $\pm 7\%$.

The experimental results show the same general

trends as those observed by La Cour (1965, 1966) and by Ferencsak, Collins, and Morgan (1971). These authors have commented on the possibility of over-infusion by using rule-of-thumb estimates of flow rates. La Cour found considerable differences between the various makes of giving sets. The present experiment shows that for the two varieties studied their performances are well-nigh the same, within experimental error.

Turning now to the diameter of the drip tube, it is interesting to observe that both Avon and Travenol sets have closely similar tube diameters. There is just a possibility that after use with blood the tube diameters are slightly reduced in both cases compared with tubes used for fluids other than blood. This would not be surprising because it is known that the plastic material is affected by contact with water solutions, and it is easy to imagine blood producing a slightly different absorption effect on the plastic.

Conclusions

The variation of drop size (drops per ml) with drip rate has been studied for samples of giving sets made by two major manufacturers in Great Britain. Although the latest products from these manufacturers are slightly modified from the designs investigated here, the drip tube dimensions are the same and hence it is unlikely that the behaviour of the latest sets would be any different from that reported here. Saline and saline-dextrose drops vary from 18 or 19 drops per ml at a rate of 20 min⁻¹ to 16 or 17 drops per ml at a rate of 100 min⁻¹. For blood the variation is less, changing from about 16 drops per ml at 20 min⁻¹ to about 15 drops per ml at 100 min⁻¹. The manufacturer's quoted drip tube delivery (drip count) is 15 drops per ml (approximately), the figure referring to distilled water as required by the British Standard. The observed drip counts for aqueous solutions lie within the range permitted by BS 2463 although the Standard applies strictly only to distilled water. From the results it is apparent that the drip tube delivery should be quoted at a given drip rate.

The diameter of the tube on which drops form

1 Litre to be infused in:	4 hr	6 hr	8 hr	10 hr	12 hr
	required drip rate per minute				
Blood	64	43	32	27	22
Sodium Chloride (BP)	70	47	36	30	25
Sodium Chloride and Dextrose (BP)	72	48	37	30	25

Table II Drops per minute to infuse 1 litre of various fluids in selected times

has been measured and been found closely constant in samples from both manufacturers.

In view of the variation of drop size with rate, perhaps manufacturers could consider providing a small table, such as table II, showing the effect for the commonly used rates. In cases where automatic infusion regulators are used this would enable more accurate timing, particularly where the infusion of drugs is concerned.

The data in table II refer strictly to Avon A11 and Travenol BR10 giving sets. The figures should give a good guide to drip rates in any set with a drip tube of internal diameter close to 3.25 mm. Thus the Avon A15 and Travenol FKC2055 can be expected to conform to the table.

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