Evaluation of 3-mm diameter intravenous tubing for the rapid infusion of fluids

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SUMMARY

The use of intravenous administration systems incorporating 3-mm internal diameter tubing is becoming more common in hospital practice. The maximum flow-rate of crystalloid solutions through 3-mm-diameter tubing is compared to that through conventional 4-mm tubing when connected to standard large-gauge intravenous cannulae.

Lengths of intravenous tubing between 80 cm and 200 cm were tested in combination with 16 gauge, 14 gauge and 13 gauge intravenous cannulae.

The results demonstrated that the use of 3-mm-diameter infusion sets, or the inclusion of even short lengths of 3-mm tubing in an infusion system, limits the maximum flow that can be delivered through a cannula of size 16 gauge or larger.

The reduced performance of the 3-mm tubing makes administration systems incorporating even short lengths of this diameter of tubing unsuitable in emergency situations and locations where rapid infusion of fluids is vital.

INTRODUCTION

It is essential that intravenous administration systems allow the rapid infusion of both crystalloid and colloid solutions in situations where emergency fluid resuscitation is required. Intravenous infusion sets incorporating 3-mm internal diameter delivery tubing are being increasingly encountered in hospital and anaesthetic practice, sometimes replacing the more usual 4-mm tubing for general purpose use.

The suitability of these smaller diameter delivery systems to provide rapid infusion rates of crystalloid fluids when connected to standard large-gauge cannulae has not

previously been investigated. This knowledge is important if giving sets are changed or extension sets incorporating 3-mm tubing are added.

This study examines the maximum flow-rates that can be achieved without the use of pressure-infusion equipment, through known lengths of 3 and 4 mm internal diameter tubing when used in conjunction with 16 gauge, 14 gauge and 13 gauge intravenous cannulae.

METHOD

Plain cut lengths of 3- and 4-mm intravenous tubing, ranging from 80 to 200 cm in length, were used. All flow-control devices, drip chambers or connecting spikes were removed. Each length of both 3- and 4-mm tubing was connected, in turn, to a water reservoir. The water in the reservoir was maintained at a height of 1 m above the delivery end of the tubing to ensure that the fluid was supplied at a constant pressure. Tap water was used for all the experiments as it has a similar viscosity to normal saline. The water from the fluid reservoir was first run through each plain length of tubing repeated again after a luer lock connector had been added to the delivery end of tubing and, finally, with the luer lock connector in combination with a 16 gauge, 14 gauge and 13 gauge cannula. The time taken for the delivery of 1 l of water was recorded on three occasions for each length of tubing. The mean time in seconds for the delivery of 1 l of water was calculated and expressed in ml/min.

All tubing connections were made through an outside connector, and the same luer lock connector and Wallace 5·7-cm intravenous cannulae were used in all tests.

RESULTS

The results show that the 3-mm tubing has a greater resistance to flow per unit length than the 4-mm tubing. This resistance to flow in the 3 mm tubing is sufficient to prevent the maximum flow of crystalloid solutions through the intravenous cannulae used. The flow was reduced when even short lengths of 3-mm tubing were used.

In Fig. 1, the results have been expressed as a percentage difference in the flow-rate between the 3- and 4-mm tubing for each cannula.

DISCUSSION

In clinical practice, a complete infusion set with connecting spike, drip chamber and flow control device will have a slower delivery rate than the test lengths of tubing would indicate. Any factors which increase the resistance to flow in the system, such as additional luer connectors and constrictions from some types of flow control device, will further reduce the flow, making the 3-mm system less efficient.

Table 1 Flow rates in millilitres per minute through the cannulae and tubing combinations¹

Tubing length (cm)	No Luer lock		Luer lock		13 gauge		14 gauge		16 gauge	
	3 mm	4 mm	3 mm	4 mm	3 mm	4 mm	3 mm	4 mm	3 mm	4 mm
200	265	631	259	571	204	320	182	253	103	120
170	297	722	288	618	223	326	189	256	107	120
140	344	810	326	689	238	340	203	271	109	122
110	408	923	389	769	263	350	221	279	113	123
80	499	1090	465	833	288	370	237	291	118	123

¹Nominal maximum flow rates for the cannulae used as quoted by the manufacturer: 16 Gauge, 121 ml/min; 14 Gauge, 251 ml/min; 13 Gauge, 326 ml/min.

The large flow rates through the 3-mm tubing alone or with a luer lock connector would suggest that the demands of any intravenous catheter should be met. When the 3-mm tubing is connected to a cannula, the manufacturers quoted maximum capacity is never reached with a progressive reduction in flow as the tubing length increases. It is important to note that the average length of tubing on an administration set lies between 150 cm and 200 cm

The final flow rate may be increased by a direct effect of raising the perfusion pressure as predicted from the Poiseuille equation, providing the flow remains laminar:

$$Q = \frac{\pi P r^4}{\mu 8 L}$$

Q = Flow rate
P = Applied pressure
L = Length of tubing
 μ = Viscosity
r = Radius of the tubing

Fig. 1 Percentage increase in flow rate of 4-mm tubing as compared to 3-mm tubing for the cannulae shown.

The increase in perfusion pressure can be achieved either by raising the height of infusion above the level of venous access or by the use of pressure infusion equipment (Dula *et al.*, 1981). Although the use of such equipment will achieve high infusion rates (Mateer *et al.*, 1985), it is not always available or easily applied in the emergency situation, and is inappropriate where glass bottled solutions are used.

The increased viscosity of plasma substitutes, albumin solutions and blood will reduce the flow rates further as an inverse function of their viscosity. When it is necessary to rapidly transfuse a viscous intravenous fluid such as blood, other workers have suggested tubing with an internal diameter of greater than 4 mm or 5 mm be employed. Both a urological fluid administration set (Nadeau & Tousignant, 1985) and 6.4-mm internal diameter tubing (Mateer *et al.*, 1985) have been used.

The suitability of systems containing even short lengths of 3-mm-diameter tubing must be questioned in certain locations, because of their reduced performance. Rapid infusion rates are routinely required during fluid resuscitation in casualty departments, surgical emergencies, anaesthetic work and obstetric practice. Large-gauge cannulae are designed to deliver rapid infusion rates and are used in these emergency situations. This makes it essential that large-gauge cannulae should not be connected to a 3-mm infusion

Table 2 Internal diameter measurements of available fluid administration sets and some additional intravenous tubing and taps

<i>Solution administration sets</i>		
Avon	A26	3.0 mm
Boots	Steriflex	3.0 mm
Braun	Accudrop	3.0 mm
	Intrafix	3.0 mm
Mallinckrodt	91269-2	3.0 mm
Travenol	C0334	3.0 mm
<i>Blood administration sets</i>		
Avon	A100	4.0 mm
Braun	Sangofix	4.0 mm
Travenol	C0271	4.0 mm
<i>Extension tubing</i>		
Avon	A60	4.0 mm
Braun		3.0 mm
Mallinckrodt	91133 to 36	2.3 mm
	91140 to 43	2.7 mm
Travenol	C0057	4.0 mm
Viggo	Connecta	2.2 mm
Vigon	220 series	2.5 mm
<i>Fluid-warming coils (Diameter of main section)</i>		
Avon	A80	4.0 mm
Portex	200/700	4.0 mm
Travenol	C2410	2.8 mm
<i>Taps and stopcocks (Diameter of narrowest lumen)</i>		
Braun	Discofix-3	1.8 mm
Mallinckrodt	91045	1.7 mm
Vigon	876.00	1.9 mm
Viggo	4614-4	1.8 mm

system which cannot deliver large flows of even crystalloid solutions. When required, short lengths of 3-mm or smaller-diameter tubing found on some extension sets and infusion ramps must be removed.

CONCLUSION

Intravenous infusion systems containing lengths of 3-mm internal diameter tubing, in combination with large-gauge intravenous cannulae, should be avoided in locations where high flow-rates are to be achieved without the use of pressure-infusion equipment.

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