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The Effects of Randomly Selected IV Serum Sets on Constant Rate Infusion: In-Vitro Demonstration*

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Abstract: Volumetric infusion pumps are electronic devices used for fluid replacement as well as constant rate infusion of anesthetic drugs. The device provides the infusion of the fluid in the set by performing peristaltic pressure on the IV (intravenous) serum set hose. Although IV sets are preferred by their peristaltic pressure properties, the random IV sets selected from the clinical field are mostly used in anesthesia. A reference infusion set which was a special product for a volumetric infusion pump, and fifteen different branded IV serum sets were used in this study. After measuring the diameters and dead spaces, serum sets were connected to the infusion pump, tap water was passed from each serum set for an hour, and collected in a graduated cylinder and measured. It was observed that the serum sets, including the reference set, may change the expected fluid volume by 19%. The diameter of the IV set affected the dead spaces and infused fluid volume. It was concluded that to overlap the expected and observed fluid volumes, the brands' infusion capacity on the pump should be tested on the device before the anesthesia for the clinical fields is a requirement.

Keywords: Constant rate infusion, Infusion pump, IV set, Serum set.

Rastgele Seçilen IV Serum Setlerinin Sabit Oranlı İnfüzyona Etkileri: In-Vitro Gösterim

Öz: Volumetrik infüzyon pompaları, sıvı replasmanlarının yanı sıra damar içi yolla belirli bir sürede anestezik bir maddenin sabit oranlı infüzyonunda kullanılan elektronik cihazlardır. İçerisine yerleştirilen IV (intravenöz) serum seti hortumu üzerine cihaz tarafından yapılan peristaltik bası, set içerisindeki sıvının ilerlemesini ve infüzyonunu sağlar. Pompalarda tercih edilmesi gereken IV setlerin her ne kadar peristaltik basıya uygun nitelikte tercih edilmesi gerekse de rutin klinik uygulamalarda çoğunlukla klinikten rastgele temin edilen serum setleriyle anestezi sürdürülmektedir. Bu çalışmada, bir tanesi volümetrik infüzyon pompası için özel üretilen referans IV serum seti olmak üzere toplam 15 farklı marka IV serum seti kullanıldı. Çapları ve içlerindeki ölü boşluklar ölçüldükten sonra infüzyon pompasına bağlanarak her bir serum setinden bir saat süreyle çeşme suyu geçirildi ve geçirilen sıvı dereceli silindir içerisinde biriktirilerek ölçüldü. Referans IV seti de dahil olmak üzere farklı IV setlerinin farklı hacimlerde sıvı gönderdiği gözlemlendi ve bu durum beklenen sıvı volümünü %19 oranında etkileyebileceğini gösterdi. IV setinin çapının ölü alanları ve infüzyonu yapılan sıvı hacmini etkilediği belirlendi. Sonuç olarak beklenen ve gözlenen infüzyon hacimlerinin birbiriyle örtüşebilmesi için klinikte kullanılan serum setlerinin cihazda önceden tecrübe edilmesinin bir gereklilik olduğu kanısına varıldı.

Anahtar Kelimeler: IV set, İnfüzyon pompası, Sabit oranlı infüzyon, Serum seti.

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INTRODUCTION

Fluid supplementation has an essential role in the clinical field, especially during anesthesia. Besides, it has a supportive effect on cardiovascular function and minimizes the impacts that anesthetic agents can cause, such as hypotension and vasodilation (1-2). Excessive fluid infusion during fluid therapy can lead to decreased pulmonary function, coagulation deficiencies, inadequate tissue oxygenation, increased infection rate, decreased body temperature (3-4).

Fluid supplementation can be done in animals by gravimetric method or by infusion pumps. Infusion pumps are electronic devices that enable intravenous infusion of fluids to the body at a specific rate and speed, have long been routinely used in the field to minimize manual infusion errors (5-7). Infusion pumps are also used to infuse general and local anesthetic agents or preanesthetic agents for epidural and regional anesthesia, especially total intravenous anesthesia (TIVA) (8-11). Recently, infusion pumps are often preferred, especially in constant rate infusion in veterinary anesthesia (12-15).

Infusion pumps vary according to the physical structure and characteristics of the device. Syringe pumps and volumetric infusion pumps are available on the market and can be used for anesthesia (16,17).

Volumetric infusion pumps are divided into two types: cassette and serum hose. Cassette pumps have a cassette interface that can be mounted on the device and helps adjust the device's flow rate, while serum hose types are milked with a peristaltic movement. The target amount of infusion fluid is provided by the serum hose inserted vertically or horizontally into the device (18). In order to infuse the correct volume, it is recommended to use iv sets specified by the manufacturer in infusion pumps (19). However, information on how common IV serum sets used by the gravimetric method in the clinic affect fluid volume when used in an infusion pump is limited.

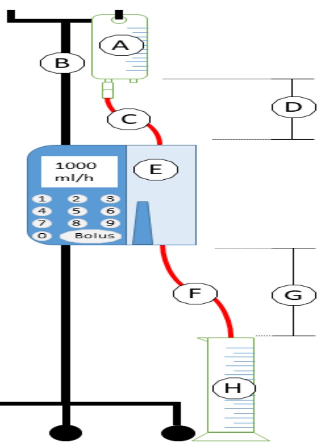
This study examines how infusion volume is affected when randomizing serum sets are preferred with peristaltic volumetric infusion pumps.

MATERIALS and METHODS

The study was carried out on 15 different IV sets, including 14 different brand serum sets used in fluid replacement by the routine gravimetric method and a reference serum set specially produced for the volumetric infusion pumps. Outer diameters of IV sets were measured with an electronic digital caliper (Carbon Fiber Composites Digital Caliper, China). The dead space for each IV set was calculated by filling the IV set with tap water.

A tap water-filled serum bag was hung on a serum hanger. An infusion pump (routinely used for TIVA in the clinic) was fixed to the serum hanger. A 30 cm distance was left between the infusion pump and serum bag. The IV set was mounted to the serum bag and placed between the hanger jaws of the volumetric infusion pump (IV Master, Birset, Türkiye). The end of the IV set was placed in a graduated cylinder (1000:10 ml, Isolab, Germany) for measuring the infused fluid volume. An 80 cm distance was left between the infusion pump and the graduated cylinder (Figure 1).

Figure 1. Drawing of the scheme of the study.
Şekil 1. Çalışmanın şemasına ait çizim.



A: Refillable serum bag, B: Serum hanger, C: IV set, D: Fixed distance (30 cm) between serum bag and pump, E: Volumetric infusion pump, F: IV set, G: Fixed distance (80 cm) between pump and graduated cylinder, H: Graduated cylinder.

The infusion pump was set to a speed of 1000 ml/h, and water was passed through each IV set for one hour; the passed fluid was collected in a graduated cylinder and measured volumetrically.

Statistical Analysis

The Kolmogorov-Smirnov test tested the normality of the observed volumes at the end of an hour. Levene's test was used for the homogeneity of the variances. Expected and observed fluid volumes were compared with independent samples t-test (95% confidence of intervals). The relationship between the volume of fluid sent by serum sets, hose diameter, and dead spaces were examined by Pearson correlation (95% confidence of intervals with one tailed). Correlation coefficients were expressed as R value.

The data were expressed as data ± standard deviation, SPSS (IBM Software, USA) software was used in statistical analysis, $P<0.05$ was considered statistically significant.

RESULTS

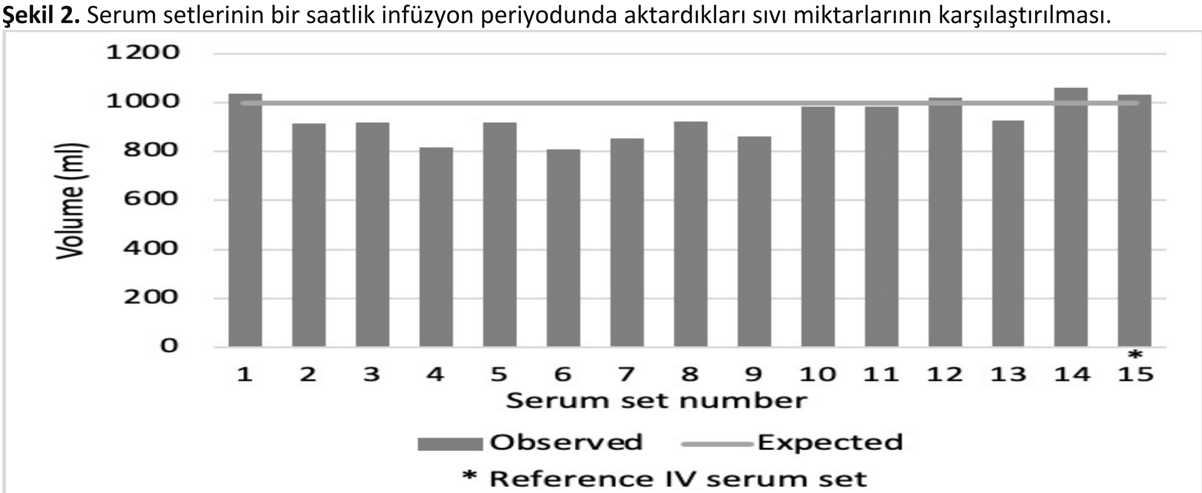
No stopping, blockage, or negative effects that would disrupt the infusion were encountered during the infusion. The data of the infusion volumes were normally distributed ($P=0.2$), homogeneity of variance was significant ($P<0.01$). The observed infusion volumes of the serum sets were statistically ($P=0.01$) lower (938.2 ± 80.3 ml) than the expected volume (1000 ml/h) (Table 1). At the end of an hour, the highest volume belonged to the set 14 as 1062 ml, and the lowest volume belonged to the set 6 as 810 ml. The three sets of serums that most closely approached the target volume were 10 (985 ml), 11 (983 ml), and 12 (1019 ml), respectively. The serum set No. 15 (reference IV set) also infused more than expected volume (totally 34 ml, Figure 2).

Table 1. Amounts of fluid infused into the graduated cylinder with IV sets at the end of the one-hour infusion period, IV set dead space volumes, and serum set diameters.
Tablo 1. Bir saatlik infüzyon süresinin sonunda IV setlerinin dereceli silindir içerisine gönderdiği sıvı miktarları, IV setlerine ait ölü boşluk hacimleri, serum seti çapları.

Serum Set No	Amount of fluid infused ml/h	Deadspace (ml)	Diameter (mm)
1	1038	16.0	3.7
2	915	14.0	3.5
3	918	14.9	3.7
4	818	14.3	3.5
5	921	15.1	3.5
6	810	15.2	3.7
7	854	15.1	3.5
8	924	16.5	3.7
9	863	14.1	3.7
10	985	14.5	3.7
11	983	15.2	3.5
12	1019	14.1	4.0
13	929	32.7	3.8
14	1062	17.6	3.7
15*	1034	29.8	4.0

*Reference IV serum set

Figure 2. Comparison of the fluid amounts for one-hour infusion period of IV serum sets.
Şekil 2. Serum setlerinin bir saatlik infüzyon periyodunda aktardıkları sıvı miktarlarının karşılaştırılması.



ml: milliliters, Observed: The volume of fluid infused within an hour period by the volumetric infusion pump, Expected: Expected volume of fluid infused within an hour period by the pump, *Reference IV serum set: Serum set (15th) which is an appropriate product for infusion pumps.

The mean diameter of the serum sets was 36.8 ± 1.7 mm, the mean dead space volume was 172.7 ± 57.8 ml. No significant relationship was observed among the infused fluid volumes ($P>0.05$). The relationship between the infused fluid volume and serum hose diameter was significantly correlated ($R=49.4$, $P = 0.03$). The dead space volumes and serum hose diameter were related significantly ($R=51.3$, $P=0.02$, Table 1).

DISCUSSION and CONCLUSION

Infusion pumps provide a predetermined flow rate of liquids and are preferred to prevent infusion errors. The constant rate infusion capabilities pave the way for the use of these pumps during anesthesia (5-7). Accurate and reliable administration of constant rate infusion anesthesia is a requirement (20-24). The random selection of the IV set during the constant rate infusion volumes can affect the infusion volume.

The results showed that there are statistically significant differences among IV sets at a rate of 1000 ml/h in the current study. Manufacturers of volumetric infusion pumps often recommend using specific IV sets calibrated for their products (19). However, we observe that the reference IV set (No. 15) was infused 34 ml of excess fluid from the expected volume. This could be possible due to the lack of calibration of the volumetric infusion pump. However, it is not known whether it is time for the calibration of the pump; IV sets were compared under the same conditions, thereby it helps to mean that the differences among infused fluid volumes of IV sets do not depend on calibration.

The results showed that those which made fluid infusions in the volume closest to the expected volume were set No. 10 (985 ml), set No. 11 (983 ml), and set No. 12 (1019 ml), respectively. This suggests that a common IV set randomized chosen in the clinic may perform better than a specially manufactured IV set for the infusion pump.

The different branded serum sets make different fluid infusions, indicating that the amount of anesthetic substances loaded into these fluids will also affect them. The differences between expected and observed volumes can affect the amount of anesthetic substance in a possible TIVA in an amount that will compromise its safety by changing the depth of anesthesia. For example, set No. 6 infused 810 ml of fluid, and this amount was 19% less than the expected volume of the fluid. This set will infuse 19% less fluid when used in anesthesia, resulting in a 19% loss of anesthetic substance. The administration of an anesthetic agent at a lower dose of 19% in planned anesthesia can cause insufficient restriction, making it difficult to control the depth of anesthesia, and is likely to cause the patient to feel pain during minor surgical interventions. We hypothesize that, in clinical practice, target flow volumes might be significantly affected because of unstabilized conditions used in veterinary clinics. We speculate these flow volumes to be considerably more remarkable in the clinical field, which directly affects the constant rate infusion anesthesia and is even more clinically meaningful.

Results showed that the diameter of the IV set affects the dead spaces and infused fluid volume. This may be originated from the IV set diameter changes contact surface of the peristaltic system and milking volume. Therefore, the measurement of the diameter of the IV set with caliper may give an idea about the deviations in the fluid flow prior to the infusion.

Several limitations must also be addressed. First, the study was conducted only in one pump. Evaluating the effects of different infusion pumps may cause different volumes. The study results were obtained with tap water, and it is not known whether the alteration of drug viscosity (e.g., propofol vs. ketamine dilutions) could significantly change the infused fluid volume.

In conclusion, fluid infusion with randomized IV sets used with volumetric pumps can change expected fluid volumes. Testing the serum set planned to be used at the pump before infusion and determining the volume deviation will reduce the faulty fluid infusions.

Conflict of interest

The authors declare that they have no conflict of interest.

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