ORIGINAL ARTICLE

Fluid replacement via the rectum for treatment of hypovolaemic shock in an animal model

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Background: The importance of early and effective fluid resuscitation in hypovolaemic shock treatment is indisputable.

Aim: To examine the effects of fluid replacement via the rectum in an animal model of hypovolaemic shock as a possible life-saving method in situations where veins cannot be accessed quickly.

Methods: Rabbits were randomly divided into two groups: a control group of 7 animals and a second group of 10, the fluid replacement via the rectum (FRVR) group. The femoral artery of each subject was catheterised and 15 ml blood was withdrawn over 1 min at 5-min intervals. After reaching a mean arterial pressure (MAP) of 30 mm Hg, additional blood was withdrawn until the MAP dropped to <25 mm Hg, at which time blood withdrawal ceased. At this point, control animals were given no treatment and were monitored for 30 min. The FRVR group, however, was given 0.9% sodium chloride solution (amount equal to three times the amount of blood withdrawn) via the rectum over a 15-min period. The MAPs of both groups were then measured, every 5 min after the start of resuscitation, for 30 min.

Results: In the FRVR group, the MAP began to rise significantly after 15 min of receiving fluid per rectum ($p=0.035$) and continued to be significantly greater than the control group at 20, 25 and 30 min ($p=0.035$, 0.002 and 0.001, respectively).

Conclusion: FRVR is a viable alternative for fluid resuscitation in this animal model of hypovolaemic shock. This easy and non-invasive method of fluid replacement may be useful when standard intravenous access is unobtainable, and should be compared with other access routes using varying types and amounts of fluids in future animal studies.

Patients with haemorrhagic shock are among those with the highest mortality in the emergency department. These patients need urgent diagnosis and treatment, for which blood and fluid replacement are fundamental.¹ If blood and fluids are not quickly given to patients with hypovolaemic shock, the deepening of shock may be followed by imminent death.² Optimum treatment entails halting haemorrhage and replacing intravascular fluids, but intravenous access is sometimes problematic for such patients, as intravascular volume loss causes a rise in peripheral-vascular resistance in both peripheral and central veins.^{3–4} In such circumstances, alternative fluid-replacement methods must be used (and can be life saving) because starting intravenous fluid replacement in patients exhibiting peripheral vasoconstriction may be impossible.^{5–7}

Fluid replacement via an intraosseous needle is rapid. This technique is often used in children, although the procedure may be difficult, is painful, and requires special equipment and sterile conditions.⁸ Intraperitoneal fluid replacement also requires special skills and equipment, must be carried out under strictly sterile conditions, and has largely been used to ameliorate organ perfusion rather than to cure haemorrhagic shock.^{9–10} Nasogastric fluids are easily given, and sterilisation is not required, but the amounts needed to overcome shock would probably induce nausea and vomiting, and the risk of fluid aspiration into the lungs is high.¹¹ A rarely used method is subcutaneous administration (hypodermoclysis) of sterile fluid, which is given into the skin around the umbilicus and abdominal wall. The amount of fluid given via this route is limited to 500–1000 cm³, should be given only once, and is usually used only in moderately dehydrated patients with terminal cancer.¹²

Although many alternative fluid replacement techniques require special skills and training, fluid replacement via the

rectum (FRVR) requires as little skill and equipment as is needed for an enema. As absorption through the rectum is adequate and the procedure is easy, rectal administration of drugs is also used in a wide variety of clinical settings.^{13–14} The colon readily absorbs fluids across its mucosa,¹⁵ and drugs (even drugs for treating shock) have been given across the colonic mucosa since the 1960s.^{16–18} Vasoconstriction, as a response to hypovolaemia, occurs throughout the whole gastrointestinal system, but after a few minutes, the “autoregulator escape” mechanism is activated and the blood flow returns to normal. The gastrointestinal arterioles dilate, and additional blood flow is provided to gastrointestinal tissues and muscles.

Absorption of ample fluid through the digestive canal is one mechanism that regulates intravascular volume in patients with shock. Between 5 and 7 l of fluid can be absorbed daily in normovolaemic people.¹⁹ Absorption of fluids in the colorectal area is greater than that in the upper gastrointestinal tract, and increases during hypovolaemia.^{15–20} Because of the ion-selectivity mechanism in the colonic mucosa, absorption of fluids with sodium in the descending colon can surpass that of the small intestine.^{21–22}

Given the simplicity and probable low-complication rate of FRVR, we set out to determine whether fluids given via the rectum were able to raise blood pressure after deep haemorrhagic shock in an animal model. We attempted to simulate the degree of shock at which obtaining intravenous access would be difficult owing to peripheral vasoconstriction.^{3–5–6}

Abbreviations: FRVR, fluid replacement via the rectum; MAP, mean arterial pressure

Figure 1 Arterial blood pressure (mean (SD)) in rabbits incrementally bled to an arterial pressure of 22 mm Hg, then observed with no treatment (controls) or resuscitated with 0.9% sodium chloride instilled in the rectum (FRVR: fluid replacement via rectum).

METHODS

This experimental study received the approval of the Faculty of Medicine's Experimental Medicine Research Center's Ethics Committee, and all animals were handled in accordance with the procedures laid out in the "Guide for the Care and Use of Laboratory Animals", prepared by the Institute of Laboratory Animals Resources, National Academy of Sciences.

Design

In all, 17 male and female New Zealand white rabbits weighing 2400–3200 g were divided randomly into a control group of 7 animals and a second group of 10, the FRVR group. The rabbits were anaesthetised with ketamine hydrochloric acid 10 mg/kg intravenous and xylazine hydrochloric acid 3 mg/kg intravenous; to maintain anaesthesia, a half-dose of the same drug was given every 30 min throughout the duration of the study. The MAP of the subjects was monitored continuously through a catheter placed in the femoral artery. About 15 ml of blood was drawn every 5 min until the MAP of each of the subjects reached 30 mm Hg. When the MAP reached 30 mm Hg, additional blood was withdrawn until the MAP dropped to <25 mm Hg, representing a deep level of haemorrhagic shock. The subjects were then divided into two groups: the control rabbits ($n = 7$), which were monitored for 30 min with no treatment, and the FRVR rabbits. To prevent fluid from leaking out of the rectum, a 12-Fr Foley catheter was inserted 5 cm into the rectum of the FRVR rabbits and inflated with 5 cm³ of air, then, three times the volume of blood withdrawn of 0.9% sodium chloride was given over 15 min through the Foley catheter into the rectum. The MAPs of the subjects in both groups were followed and recorded at 5-min intervals until 30 min after the start of fluid resuscitation.

On our pilot study of this model in several rabbits, the rectum was perforated, owing to our lack of rabbit-enema experience. Cleaning the rectum with 3–5 cm³ of water before the experiment eased the administration of the resuscitation fluid, and the use of gel eased the placement of the Foley catheter and prevented faeces from obstructing the gut. The Foley catheter was inserted only 5 cm into the rectum, and the balloon was inflated with only 5 cm³ of air.

With these precautions, no rectal damage occurred in the study animals.

Statistical analysis

Data were analysed with SPSS V.11.0 for Windows. Arithmetical means and standard deviations were calculated. Because of small sample sizes and non-normal distribution of data (as determined by Shapiro–Wilks testing), the Mann–Whitney U test was used.

RESULTS

The mean weight of the seven rabbits in the control group was 2812 (SD 425) g and the average MAP at the beginning of the study was 65 (SD 8) mm Hg. The mean quantity of blood withdrawn was 60 (SD 9) ml, and the MAP dropped to <25 mm Hg in a mean time of 20 (SD 4) min.

The average weight of the 10 rabbits receiving FRVR was 2849 (SD 257) g and the mean MAP at the beginning of the study was 64 (SD 10) mm Hg. The average quantity of blood drawn was 55 (SD 11) ml, and the average time at which the MAP dropped to <25 mm Hg was 17.0 (SD 3.5) min. No statistical difference was found between the two groups regarding the time to development of severe shock (MAP <25 mm Hg).

In the control group, the mean lowest MAP was 22.1 (SD 3.6) mm Hg when the 30-min observation period was begun. The MAP of the FRVR rabbits dropped to a low of 21.7 (SD 2.5) mm Hg, after which FRVR was begun. The MAP peaked in the FRVR rabbits at 38.1 (SD 6.9) mm Hg at 30 min after resuscitation was started ($p = 0.001$; fig 1), whereas the mean peak MAP in the control animals was 21.4 (SD 5) mm Hg at 30 min.

Limitations

The gastrointestinal system is innervated parasympathetically (afferent fibres from the distal colon go through the pelvic plexus). A sham group was not used because blood pressure would not be expected to rise secondary to placement of a rectal catheter alone.¹⁹

To determine the amount of fluid to be used for resuscitation of the rabbits, the amount of bleeding had to be measured; thus, a controlled-shock model was used, as

opposed to an uncontrolled-bleeding model. Because the blood volume/kg of a rabbit can vary considerably, we bled the rabbits to a pre-determined level of MAP as opposed to removing a fixed volume of blood.

Although the gastrointestinal system of a rabbit is quite different in some respects from humans, it has been used quite often for shock-research studies, although to date none were concerned with the administration of rectal fluids. This was also the easiest animal model for our laboratory to accommodate, and was a pilot project to examine this type of fluid resuscitation model.

In this study, the MAP of the rabbits decreased to about 22 mm Hg, which is a level much lower than in other shock studies (35 (SD 5) mm Hg).²³ Most of the subjects in the pilot study died within 1 h and the remainder died within 24 h. However, our aim was to reach this level of shock to properly represent patients in whom intravenous fluid administration could not be started and FRVR might be attempted. As all the rabbits in the pilot study died within 1 h, we decided to measure and analyse the physiological variables over the first 30 min of resuscitation.

DISCUSSION

Although intravenous fluid replacement should be attempted first in patients with hypovolaemic shock, intravenous access may be difficult in these patients for many practitioners. Frequently cited alternative methods for emergent fluid administration, such as intraosseous and intraperitoneal, must be ready to be performed,^{3 5 6} but these also necessitate expertise and sterile equipment.^{12 24} In contrast, FRVR requires no sterile fluids, special equipment or complex training.

When considering intraosseous or intraperitoneal fluid administration, it should be noted that osteomyelitis and compartment syndrome may arise from intraosseous, and peritonitis from intraperitoneal fluid administration.²⁵ Pain, which accompanies intraosseous and subcutaneous access, is also difficult to prevent.¹² For the intraperitoneal method, surgical tools and special catheters are essential, and the intraosseous option requires special needles.^{10 24} FRVR is painless and requires no special equipment—only an enema set, aspirator tip and Foley catheter. The purpose is to deliver fluids without damaging the anal canal or the gastrointestinal tract.

FRVR may be used in many settings, and several litres of fluid can be given in minutes. Subcutaneous fluid replacement is slower, and the maximum amount of fluid that can be safely given is quite small.^{6 12} Intraperitoneal and intraosseous fluid administration may be difficult to carry out in the prehospital setting.²⁴ Giving fluids via a nasogastric tube is a simple task that requires no sterile equipment, but vomiting is common in patients in shock. Nasogastric tubes should be used for gastric decompression during shock, not for fluid administration.¹¹ The subcutaneous application is not suitable for patients with shock, as the subcutaneous vascular circulation is reduced. No studies of nasogastric or subcutaneous fluid administration for shock are found in the literature.²⁴

Cannon¹⁷ described his experiences with FRVR during World War I in his 1923 book *Traumatic shock*, and Hardaway,¹⁸ in his book *Care of the wounded in Vietnam*, mentions the use of FRVR for non-emergent cases and states that this method did not allow enough fluids to be given fast enough to treat shock. Our search for modern research on FRVR found no animal or clinical human studies on the effects of this method in the treatment of hypovolaemic shock.

CONCLUSION

Considering the deep-shock state induced in these rabbits, the success of FRVR is worth noting. Nevertheless, unlike

other fluid replacement methods, FRVR should never replace intravenous access, and should be discontinued after intravenous access is established. Further research on using FRVR should be carried out in other animal models to determine its useful limits with varying degrees of shock, for varying time periods and with different fluids.

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REFERENCES

- Shafi S, Kauder DR. Fluid resuscitation and blood replacement in patients with polytrauma. *Clin Orthop Relat Res* 2004;**422**:37–42.
- Lucas CE. Resuscitation through the three phases of hemorrhagic shock after trauma. *C J Surg* 1990;**33**:451–6.
- Vyskocil JJ, Kruse JA, Wilson RF. Alternative techniques for gaining venous access. What to do when peripheral intravenous catheterization is not possible. *J Crit Illn* 1993;**8**:435–42.
- Schwartz SI, Shires GT, Spencer FC, et al. *Principles of surgery*, 7th edn. New York: McGraw-Hill, 1999.
- Orgiler Uranga PE, Navarro Arnedo JM, De Haro Marin S. The intraosseal route. When the veins have disappeared. *Enferm Intensiva* 2001;**12**:31–40.
- Vyskocil JJ, Kruse JA, Wilson RF. Techniques for vascular access when venous entry is impossible. Route depends on urgency and the agent to be administered. *J Crit Illn* 1993;**8**:539–45.
- Greaves I, Porter KM, Revell MP. Fluid resuscitation in pre-hospital trauma care: a consensus view. *J R Coll Surg Edinb* 2002;**47**:451–7.
- Banerjee S, Singhi SC, Singh S, et al. The intraosseous route is a suitable alternative to intravenous route for fluid resuscitation in severely dehydrated children. *Indian Pediatr* 1994;**31**:1511–20.
- Zakaria el R, Hurt RT, Matheson PJ, et al. A novel method of peritoneal resuscitation improves organ perfusion after hemorrhagic shock. *Am J Surg* 2003;**186**:443–8.
- Garrison RN, Conn AA, Harris PD, et al. Direct peritoneal resuscitation as adjunct to conventional resuscitation from hemorrhagic shock: a better outcome. *Surgery* 2004;**136**:900–8.
- Nager AL, Wang VJ. Comparison of nasogastric and intravenous methods of rehydration in pediatric patients with acute dehydration. *Pediatrics* 2002;**109**:566–72.
- Farrand S, Campbell AJ. Safe, simple subcutaneous fluid administration. *Br J Hosp Med* 1996;**55**:690–2.
- Tamai I. Molecular characterization of intestinal absorption of drugs by carrier-mediated transport mechanisms. *Yakugaku Zasshi* 1997;**117**:415–34.
- Shareef MA, Khar RK, Ahuja A, et al. Colonic drug delivery: an updated review. *AAPS Pharm Sci* 2003;**5**:17.
- Muranishi S. Characteristics of drug absorption via the rectal route. *Methods Find Exp Clin Pharmacol* 1984;**6**:763–72.
- Bender AD. Effect of age on intestinal absorption: implications for drug absorption in the elderly. *J Am Geriatr Soc* 1968;**16**:1331–9.
- Cannon WB, ed. *Traumatic shock*. New York: D Appleton and Co, 1923.
- Hardaway RM, ed. *Care of the wounded in Vietnam*. Manhattan, KS: Sunflower University Press, 1988.
- Guyton AC, Hall JE, eds. *Textbook of medical physiology*, 10th edn. Philadelphia: Saunders, 2000.
- Baumgart DC, Dignass AU. Intestinal barrier function. *Curr Opin Clin Nutr Metab Care* 2002;**5**:685–94.
- Davis GR, Santa Ana CA, Marowski SG, et al. Permeability characteristics of human jejunum, ileum, proximal colon and distal colon: results of potential difference measurements and unidirectional fluxes. *Gastroenterology* 1982;**83**:844–50.
- Scharrer E, Medl S. The electrical potential difference, short circuit current and Na⁺ and Cl[–] transport across different segments of sheep colon. *Comp Biochem Physiol A* 1982;**73**:413–16.
- Komori M, Takada K, Tomizawa Y, et al. Effects of colloid resuscitation on peripheral microcirculation, hemodynamics, and colloidal osmotic pressure during acute severe hemorrhage in rabbits. *Shock* 2005;**23**:377–82.
- Garrison RN, Zakaria el R. Peritoneal resuscitation. *Am J Surg* 2005;**190**:181–5.
- Galpin RD, Kronick JB, Willis RB, et al. Bilateral lower extremity compartment syndromes secondary to intraosseous fluid resuscitation. *J Pediatr Orthop* 1991;**11**:773–6.