

# USING BODY WEIGHT AS A PRE-HOSPITAL FLUID INFUSION DEVICE: THE RELATIONSHIP BETWEEN UNDER-BODY POSITION AND FLOW RATE

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## Summary

This study was designed to identify the most effective under-body position when using the patient's own body weight as an infusion device. Twenty volunteers had an air-less 500ml bag of saline located at various under-body positions. Mean pressures and flow rates through a 14G cannula were measured in vitro at room temperature. Locating the fluid bag at the buttock cleft delivered the highest mean flow rate at 135ml/min. This under-body position may provide flow rates sufficient to achieve the clinical aim of fluid resuscitation in the military pre-hospital environment.

## Introduction

In the field suspending intravenous (IV) crystalloids above the patient to establish an infusion using gravity, may not always be achievable [1, 2]. The patient's own body weight may be used as an infusion device and this technique has been proposed as a military pre-hospital fluid infusion strategy. The technique has clear advantages on manpower and minimizes the risk of accidental complications, e.g. venous air embolism and dislodgement of the IV cannula.

Normal variations in physique, obesity patterns and the relationship between body weight distribution and gender, may affect the efficiency of a specific under-body position to compress the bag of fluid. A recent investigation using sacral compression to infuse fluid produced relatively low (40 ml/min) mean flow rates and demonstrated a poor correlation between flow and bodyweight [2].

Flow is determined by the Hagen Poiseuille equation, but if we exclude the constants from the equation ( $\pi$ ,  $r$ ,  $\mu$ ,  $l$ ) then flow is directly proportional to the pressure gradient, which is proportional to the height of a column of liquid (hydrostatic pressure). During fluid administration the venous pressure ( $P_v$ ) adjacent to an IV cannula is unlikely to fluctuate more than 1-2 mmHg during the respiratory cycle. If we assume that the pressure gradient ( $\delta P$ ) is equivalent to the pressure at the end of the fluid administration set ( $P_f$ ), then flow is directly proportional to  $P_f$  (Figure 1). The flow rate of liquid through IV cannulae (Table 1) is measured using standardised conditions, which involves suspending a 1 litre bag of fluid with uniform density at a height of 1m above the cannula. A comparison of the in vitro pressures and flow rates generated by gravity with under-body compression has not been reported [3].

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$$\bullet \text{ Flow} = \delta P \pi r^4 \div 8 \mu l$$

$$\bullet \text{ Flow} \propto \delta P$$

$$\bullet \delta P = P_f - P_v$$

$$\bullet \text{ Flow} \propto P_f$$

Figure 1. The Hagen Poiseuille equation. When venous pressure ( $P_v$ ) is negligible, flow becomes directly proportional to the pressure at the end of the fluid administration set ( $P_f$ ).

Gauge / Colour	Flow Rate (ml/min)
22 GA BLUE	31
20 GA PINK	54
18 GA GREEN	80
16 GA GREY	180
14 GA BROWN	270

Table 1. Relationship between gauge and flow rate for intravenous cannulae (BD Venflon, Helsingborg, Sweden).

We would expect effective under-body compression of a bag of fluid to produce high pressures ( $P_f$ ) and high flow rates, but the location of the most effective under-body position has not been reported. This study was designed to identify the most effective gender specific under-body position to compress a 500ml bag of crystalloid, using the subject's own body weight as an infusion device.



Figure 2. Transducer configuration attached to an air-less intravenous fluid infusion set for measuring pressure ( $P_f$ ).

**Methods**

Healthy adult volunteers with a normal physique were invited to participate in the study. Each subject had their height, weight and Body Mass Index (BMI) recorded and was then positioned supine on a NATO stretcher.

*Part 1*

A 500ml bag of 0.9% sodium chloride attached to an intravenous fluid infusion set (RMC2071, Baxter, Newbury, UK) with all the air expelled, was connected as shown in Figure 2 to a pressure transducer system (Transpac IT, Abbott, Sligo, Ireland). The system was zero-calibrated and the pressures displayed using standard monitoring (S/5, Datex Ohmeda, Stirling, UK). With the bag of saline suspended 1m above the transducer (control location) and following a period of stabilisation, three mean pressure measurements were recorded. Using a random order for each subject, the bag of saline was re-positioned at six under-body locations: Heels, buttock cleft, sacrum, interscapular region, cervical spine and occiput. Following a period of stabilisation, three mean pressure measurements, separated by minor adjustments in posture, were recorded at each of the six positions for every subject.

Using a 50ml syringe and 3 way stopcock, 100ml was removed from the bag of saline. Three mean pressure measurements were recorded (as above) with the bag positioned in random order at the control location and at two under-body locations: the interscapular region and buttock cleft. The highest mean pressures were generated at these locations during the pilot study [3]. This method was repeated for every subject and pressure measurements recorded with 300ml, 200ml and 100ml of saline remaining in the bag.

*Part 2*

A full 500ml bag of 0.9% sodium chloride attached to the airless fluid infusion set (as above) and connected to a 14G cannula (BD Venflon, Helsingborg, Sweden) was clamped off. The bag of saline was then positioned at the 1m high control location. The infusion set was unclamped and the volume of liquid which was ejected through the cannula was collected and accurately measured. The time from unclamping the infusion set to the point when the flow of saline through the cannula became negligible was recorded and the average flow rate at room temperature was calculated in ml/min. This method was repeated and the flow rate calculated with the bag of saline positioned in random order at the interscapular region and buttock cleft for all subjects.

**Results**

Twenty volunteers were recruited into the study and the demographic data for each gender is shown in Table 2.

	Male	Female
Age	29 (22-44)	31 (26-38)
Height (m)	1.78 (1.75-1.86)	1.68 (1.55-1.79)
Weight (Kg)	83 (72-106)	64 (53-81)
BMI	26.9 (22.5-30.6)	23.7 (21.6-29.4)

Table 2. Demographic data for the study population. Data are presented as mean and range.

The mean pressure measured (Pf) following compression of a 500ml bag of saline at the six under-body locations is shown in Table 3. The highest mean pressures were measured at the buttock cleft, interscapular region and sacrum.

The relationship between the remaining volume of saline and the mean pressure (Pf) measured with the bag at the buttock cleft and interscapular region for both genders and at the control location is shown in Figure 3. The greatest reduction in

mean pressure occurred between 500 and 400ml at both male under-body locations. The subsequent decay in mean pressure was similar for all under-body locations.

Position	Male	Female
Occipital	30 (27-30)	31 (26-38)
Neck	5 (3-6)	14 (12-15)
Interscapular	105 (100-106)	75 (73-78)
Sacral	99 (98-102)	54 (52-56)
Buttock Cleft	120 (115-125)	85 (82-87)
Heels	55 (53-57)	43 (41-45)

Table 3. Relationship between the pressures measured (Pf) following compression of a 500ml bag of saline at different positions. Pressure is measured in mmHg and data are presented as mean and range. The control Pf was 69 mmHg.

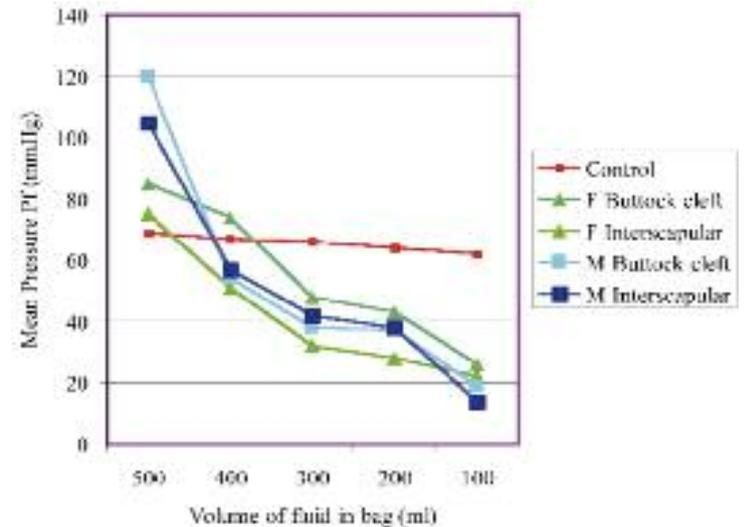


Figure 3. Relationship between volume of saline in bag (ml) and the mean pressure (Pf) measured at three different positions. Data are presented for the control and the data for both genders at the buttock cleft and interscapular region.

The mean flow rates through the 14G cannula with the bag of saline at different locations is shown in Table 4. The mean flow rate at the control location was 192 ml/min, which is 71% of the flow through a 14G cannula using a 1 litre bag at standard conditions. The mean under-body flow rate achieved with the bag of saline in the buttock cleft was 70% and 61% of the control for male and females respectively. At the interscapular region the mean under-body flow rate was 59% and 51% of the control for male and females respectively.

	Flow Rate (ml/min)	Infusion Time (sec)	Volume Infused (ml)
Control	192	150	480
Buttock cleft (Male)	135 (126-138)	195 (184-208)	440 (399-459)
Buttock cleft (Female)	118 (111-130)	211 (194-218)	415 (401-429)
Interscapular (Male)	113 (104-129)	215 (209-221)	405 (386-421)
Interscapular (Female)	98 (90-103)	231 (211-238)	377 (340-396)

Table 4. Relationship between position of the bag of saline and the flow rate through a 14G cannula. Data are presented as number or mean and (range).

**Discussion**

The effectiveness of the buttock cleft and interscapular region as under-body infusion locations was similar for each gender. Ease of placement of the bag in the field and patient tolerance of the technique are crucial factors in determining the optimal

location. Our data for both genders indicates that the buttock cleft is the optimal location for effective under-body compression of a 500ml bag of saline. Therefore, it should be used as the primary location when using this technique to infuse pre-hospital fluids. The interscapular and sacral regions should be reserved as alternative locations.

The mechanism of injury must be known prior to using under-body compression as an infusion technique and if a specific location risks exacerbating known or potential injuries, then an alternative under-body location or a gravity-fed infusion should be considered.

In the military pre-hospital environment, when haemorrhage occurs from a non-compressible source and the time to surgery is within operational timelines, permissive hypotension may be practiced [4, 5]. Avoiding aggressive fluid resuscitation in these circumstances is essential as it may affect outcome. BATLS guidelines for fluid resuscitation following penetrating injury and blunt non-head injury, advocates titrating 250ml boluses of crystalloid to maintain a radial pulse, or to achieve a systolic pressure of 80mmHg [6].

We accept that a limitation of our study to military pre-hospital practice is the limited availability of 500ml bags of isotonic crystalloid solutions on UK medical operations. However, including 500ml bags of crystalloid within pre-hospital modules would reinforce the current doctrine of avoiding excessive fluid resuscitation. Providing the lighter 500ml bags would complement clinical vigilance and minimize the risk of excessive IV fluids being inadvertently administered.

Large bore IV cannulae or intraosseous devices are routinely used to administer pre-hospital resuscitation fluids [7, 8]. When using gravity to infuse fluid from the 500ml bag suspended at 1m, the mean flow rate through the 14G cannula was lower than known flow rates through this cannula (Table 1). This emphasises the advantages of suspending fluids at head-height, which generates higher hydrostatic pressures and flow rates for a given volume of fluid. The ability to suspend the bag of fluid above the height of the casualty exists on most wheeled and rotary ambulances, so standard flow rates through IV cannulae may be quickly restored or increased [9]. This may be clinically indicated when pre-hospital times are extended as continuing to practice permissive hypotension or limiting resuscitation volumes beyond one hour, may result in end-organ failure or death [10]. To achieve the maximum benefit from a large-bore cannula, a suitably large vein should be cannulated [11].

When the bag of saline is located at the buttock cleft there is a theoretical risk of bacterial contamination, so as a precaution the bag and fluid administration set should be replaced when gravitational infusion has commenced.

This study reinforces the proposal of using the patient's own bodyweight as an infusion device in the military pre-hospital environment. The primary under-body location for compressing a bag of fluid is the buttock cleft, which generates the highest mean flow rates in both genders. The technique can deliver within 220sec, mean volumes greater than 400ml, which could achieve the clinical aim of fluid resuscitation in pre-hospital settings. Further research is recommended using a larger population sample, in order to confirm our findings and to establish the future role for this technique.

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