THE INTRAOSSEOUS ROUTE IS A SUITABLE ALTERNATIVE TO INTRAVENOUS ROUTE FOR FLUID RESUSCITATION IN SEVERELY DEHYDRATED CHILDREN

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ABSTRACT

It is sometimes difficult to gain a rapid intravenous access in hypovolemic states. The suitability of intraosseous (IO) route for fluid infusion as an effective, safe and reliable alternative to intravenous (IV) route was explored.

Sixty children (age range 3 months to 2 years) with severe dehydration were assigned alternately to receive resuscitating fluid through either IO or IV routes. The IO route was successfully secured in all cases within the first 5 minutes of attempt. On the other hand, the IV line could not be secured in 33% (10 out of 30) patients within 5 minutes. The time taken for TV *cannulation when it was successful (129 ± 13 seconds, 95% confidence interval 103-156 seconds) was significantly longer than the time taken for IO cannulation (67 ± 7 seconds, 95% confidence interval 55-80 seconds). Fluid infusion through either routes was equally effective in stabilizing vital signs and normalizing laboratory abnormalities. No significant complication of IO route was noted on short term follow-up. We conclude that 10 route is a safe, effective alternative for emergency fluid administration in severe dehydration when intravenous line can--not be secured rapidly.*

Key words: *Severe dehydration, Intravenous, Intraosseous.*

It is critical to establish an intravenous access rapidly in severely dehydrated children for fluid infusion. This is often not possible when the veins are not visible or palpable due to peripheral vascular collapse. Percutaneous cannulation of large veins (femoral/subclavian) is difficult and venous cutdown is time consuming. Hence there is a need for a rapid, effective, easy and safe alternative to intravenous route for fluid resuscitation.

Drinker *et al*.(l) and Doan(2) in 1922 demonstrated the adequacy of the bone marrow for fluid infusion in experimental animals. Soon intraosseous route became extremely popular as evident from several publications in 1940s(3-6). After years of neglect, the use of this route is showing resurgence for emergency drug(7-9) and fluid therapy(10-12). The intraosseous route utilizes the rich vascular network of long bones for transport of fluids and drugs from the medullary cavity to the circulation. It is clearly superior to intradermal clysis or intraperitoneal infusion of fluids(13).

The aim of our study was to explore the suitability of the intraosseous route as an alternative to intravenous route for fluid resuscitation in severely dehydrated children. The specific objectives of this study were as follows: (i) Comparison of the efficacy of intravenous (IV) and intraosseous (IO) routes of fluid infusion in severely dehy-

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drated patients as regards stabilization of vital signs, correction of dehydration, change in serum osmolality and improvement in metabolic acidosis; and *(ii)* To study the feasibility of each method as regards success rate at the end of 5 minutes, average time taken and acute complications, if any. This study is the first controlled trial comparing the ease of insertion of intraosseous and intravenous infusions and we are not aware of any previous study which has critically compared these two routes in the clinical setting of severe dehydration.

Material and Methods

For the intravenous route 22 or 24G teflon catheters (Viggo), and for intraosseous route 18G spinal needles with stylet (Vygon) or 16-18 G hypodermic needles with stylet were used. The initial resuscitating fluid was normal saline and/or N/2 saline in 5% dextrose (with potassium 20 mEq/L, if not contraindicated).

Pretesting

Intraosseous route is being frequently used in our Emergency Unit when expeditious intravenous cannulation is not possible during resuscitations. The pediatric residents who participated in the study, therefore, had the requisite skill for both intravenous and intraosseous cannulations.

Clinical Methods

All clinical parameters were recorded by one of the investigator. The clinical dehydration score took into account general appearance and condition, urine flow, strength of radial pulse, systolic blood pressure, moistness of mucosa, skin turgor, level of fontanelle, nature of breathing and state of eyeballs (scores 1 for mild, 2 for moderate and 3 for severe dehydration). Total score more than 20 indicated severe dehydration(14). Although, a study by Mackenize *et al*.(15) suggests that a clinical estimate of the severity of dehydration, may be inexact and subjective, the use of these physical signs is still the best method for clinical assessment of dehydration, and is recommended by the WH0(14) and standard text books(16).

Laboratory Methods

Blood samples were analysed for serum sodium/potassium (by flame photometry), blood urea (by diacetyl monoxime method), serum creatinine (by Jaffe's reaction), plasma osmolality (by freezing point depression techniques) and arterial blood gases (using BMS-3 MK-2 blood microsystem, Radiometer, Copenhagen).

Sample and Study Design

Sixty children with severe dehydration due to diarrhea and/or vomiting, age ranging from 3 months to 2 years, constituted the study population. The patients were placed into one of the two groups, intraosseous or intravenous, alternately and protocol shown in *Fig. 1* was followed.

As all the patients with severe dehydration have circulatory instability, normal saline was infused over first 2 hours, according to the standard WHO recommendation that is followed in our unit(17) (1st hour: <1 year-30 ml/kg, >1 year-20 ml/kg, 2nd hour: <1 year-20 ml/kg, >1 year-15 ml/kg). After this the patients received oral rehydration solution (ORS) if they were able to drink and were not vomiting; otherwise the intravenous fluid infusion was continued till the oral administration of ORS was possible.

Evaluation Parameters

Success was defined as the ability to start the fluid infusion within first 5 minutes

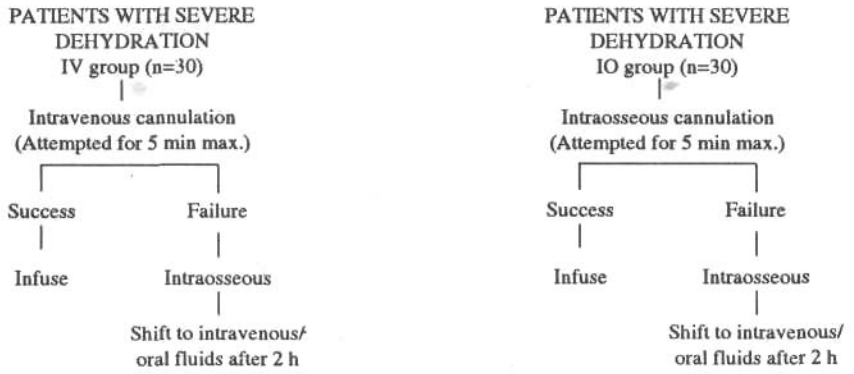

Fig. l. Patients were alternately placed into IV group (n=30) and IO group (n=30) and the protocol shown above was}

of attempt at cannulation. Venous blood samples were collected at the beginning of infusion whenever possible (0 min sample). In patients with peripheral vascular collapse when venepuncture was not possible before starting the infusion, the first possible sample was designated as 0 min sample. Second venepuncture (120 min sample) was done 2 hours after the first. The time spent for starting intravenous and intraosseous infusions (skin puncture to starting the drip) was recorded by an assistant using an electronic stop watch (usually the attending nursing staff).

Statistical Analysis

Mann-Whitney U test was used for analysing the differences in the time taken to achieve either intraosseous or intravenous routes. The same test was used to analyse the differences in the clinical parameters among the patients in whom intravenous cannulation was successful and in whom it failed. The changes in clinical and laboratory parameters of patients with severe dehydration after fluid infusion were analyzed by using paired 't' test. The 95% confidence interval (CI) was calculated using standard method(18).

Results

Patients belonging to either intravenous or intraosseous groups (30 each) were comparable in age and duration of various presenting symptoms *(Table I)*. Hyponatremia (<130 mEq/L) was seen in 13%, hypokalemiak(<3.5 mEq/L) in 15%, hyperkalemia (>5.5 mEq/L) in 23% and acidosis (pH <7.2) in 23% cases. None of the patients had hypernatremia.

The intravenous cannulation was successful in 66% cases while the intraosseous route could be achieved in all the 40 cases (30 from the intraosseous group and 10 from the intravenous group in whom IV line could not be secured). Intraosseous route was attempted within first 5 minutes of unsuccessful intravenous attempt. Even for the cases in the IV group who could be successfully cannulated within the initial 5 minutes, the time taken (129 ± 13) seconds, 95% CI 103-156 seconds) was nearly twice the time taken for intraosseous cannulation (67 ± 7 second, 95% CI 55-80 seconds). The difference in these values was statistically significant at $p < 0.001$ *(Table II)*.

A comparison of the clinical characteristics of the cases within the IV group in

TABLE I– *Patient Characteristics at Study Entry: Age Distribution and Duration of Various Presenting Symptoms*

	Group	No. of patients (%)	Range	Mean ± 2 SEM
(*a*) Age (mo)	IV	30	3-18	8.6 ± 1.6
	IO	30	3-24	8.9 ± 2.0
(*b*) Duration				
1. Watery stool	IV	30 (100)	1-6 d	2.0 ± 0.4 d
	IO	29 (97)	1-5 d	2.1 ± 0.3 d
2. Large stool volume	IV	30 (100)	1-3 d	1.6 ± 0.2 d
	IO	28 (93)	1-3 d	1.9 ± 0.3 d
3. Vomiting	IV	5 (17)	1-2 d	1.2 ± 0.4 d
	IO	9 (30)	1-3 d	1.7 ± 0.4 d
4. Oliguria	IV	24 (80)	10-48 h	24.8 ± 4.5 h
	IO	27 (90)	8-48 h	26.9 ± 3.6 h
5. Anuria	IV	10 (33)	6-12 h	9.8 ± 1.2 h
	IO	17 (57)	6-20 h	12.6 ± 2.7 h
6. Abdominal distension	IV	6 (20)	4-24 h	13.6 ± 6.9 h
	IO	4 (13)	2-24 h	7.5 ± 11.0 h
7. Deep rapid breathing	IV	18 (60)	2-24 h	8.2 ± 3.0 h
	IO	16 (53)	4-10 h	7.1 ± 1.0 h
8. Convulsion	IV	4 (13)	2-24 h	7.5 ± 1.0 h
	IO	7 (23)	2-8 h	6.3 ± 1.8 h
9. Altered sensorium	IV	28 (93)	2-24 h	6.9 ± 1.6 h
	IO	28 (93)	4-24 h	7.9 ± 1.6 h

TABLE II– *Failure Rate and Time Taken–Intravenous (IV) Route Compared with Intraosseous (IO) Route*

	Parameter	IV Route	IO Route	
1.	Failure rate	10/30 (33%)	0	p <0.001
2.	Time taken (sec) mean ± SEM (95% CI)	129±13* (103-156)	67±7# (55-80)	p <0.001
3.	Time range (sec)	45-252*	30-150#	

* n = 20, # n = 40.

whom the initial intravenous cannulation failed (n=10) with these in whom it was successful (n=20) revealed that the failed cases had significantly lower blood pressure, greater heart rate, higher dehydration score and longer capillary filling time ($p<0.001$) *(Table III)*. Both the routes of fluid infusion were effective in stabilizing vital signs, elevating systolic blood pressure *(Fig. 2),* improving peripheral perfusion, correcting dehydration, normalizing plasma osmolality and improving acid-base status *(Fig. 3)* in patients with severe dehydration *(Table IV)*. Volume expansion with intravenous or intraosseous infusion caused statistically significant fall ($p<0.001$) in blood urea and serum creatinine. Fractional excretion of sodium in urine increased with fluid infusion *(Table V)*. No significant difference was found in the efficacy of these two routes when the changes in clinical and laboratory parameters after 2 hours of fluid infusion were compared.

Discussion

We found that intraosseous access could be secured within 5 minutes in all the 40 patients (30 from 10 group and 10 from IV group in whom intravenous cannulation failed) with severe dehydration in whom it was attempted and in 90% of them in first attempt. On the other hand, an intravenous access could be established in 66% patients only within first 5 minutes; in one third patients it was unsuccessful. Kanter *et al.(19)* while evaluating a protocol for emergency intravenous access in pediatric population found the success rates of peripheral venous cannulation during initial 3 minutes to be only 39% and 66% during initial 5 minutes-results which are quite similar to our own. The same authors were able to successfully secure the intraosseous route in 5 out of 6 cases.

Pediatric residents with one year clinical experience encountered no difficulty in securing intraosseous line expeditiously. Though the intravenous line could not be achieved within the initial 5 minutes in 33% cases, once the dehydration was corrected, cannulation could be done without much

TABLE III– *Hemodynamic Variables and Dehydration Scores of Children in IV Group at Study Entry: Failed Cases Compared with the Cases in whom IV Cannulation was Successful*

Viarables	Failed cases (n=10)	Successful cases (n=20)	
1. Heart rate/min	178±11 (166-190)	156±6 (150-163)	p <0.001
2. Systolic BP (mm Hg)	53±3 (48-59)	64±2 (61-68)	
3. Dehydration score	26±1 (25-27)	23±1 (22-24)	
4. CFT	4.2±0.2 (3.7-4.6)	3.2±0.1 (3.0-3.5)	

All values expressed as mean ± SEM (95% Confidence interval).
CT–Capillary filling time.

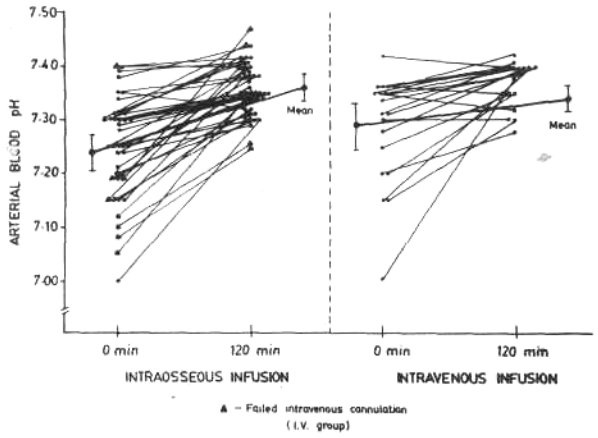

Fig. 2. Changes in arterial blood pH with fluid infusion through IO route (n=40, 30 from IO group and 10 from IV group in whom IV cannulation failed) and IV route (n=20, these were the cases in whom IV cannulation was successful).

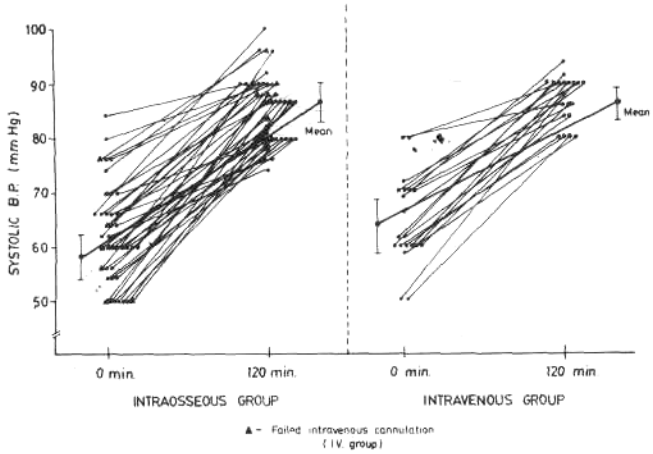

Fig. 3. Changes in systolic blood pressure with fluid infusion through 10 and IV routes.

difficulty. Needless to say, repeated attempts at cannulation not only result in wastage of time but also lead to damage to intact veins and thereby preclude successful cannulation later. Since the failure to cannulate peripheral veins expeditiously were seen mostly in those cases with hypotension and peripheral vascular collapse, we suggest that one should consider intraosseous route for fluid resuscitation when peripheral veins are not visible and cannot be rapidly cannulated, specially in a

TABLE IV–*Change in Vital Signs, Plasma Osmolality and Acid-Base Status with Fluid Infusion*

Variables*	IV (n=20)#		IO (n=40)#	
	Omin	120 min	Omin	120 min
1. HR/min	156±6	116±4	166±6	122±4
2. RR/min	54±4	39±1	61±4	43±2
3. Systolic BP (mm Hg)	64±4	87±2	58±3	86±2
4. Diastolic BP (mm Hg)	48±3	61±2	43±2	62±2
5. CFT (sec)	3.2±0.2	1.9±0.1	3.8±0.2	1.9±0.2
6. Dehydration score	23±1	11±1	25±1	12±1
7. Plasma Osmol (mosm/kg)	291±3	285±2	301±4	288±2
8. pH	7.29±0.04	7.34±0.02	7.24±0.03	7.36±0.02
9. HCO_3 (mmol/L)	11.90±1.45	17.85±1.98	9.95±1.19	16.56±1.13
10. PCO_2 kPa (mm Hg)	3.2±0.3 (24±2)	4.1±0.4 (31±3)	2.9±0.3 (22±2)	4.0±0.3 (30±2)

* Mean ± SEM, # p <0.001.

HR–Heart rate, RR–Respiratory rate, CFT–Capillary filling time.

TABLE V–*Mean Serum Electrolytes, Creatinine, Blood Urea and Fractional Sodium Excretion Before and After Fluid Infusion*

Variables*	IV (n=20)#		IO (n=40)#	
	0 min	120 min	0 min	120 min
1. Serum Na^+ (mmol/L)	134±2 (124-145)	132±2 (128-149)	138±2 (115-150)	133±1* (128-140)
2. Serum K^+ (mmol/L)	4.4±0.7 (3.0-7.0)	3.9±0.3 (2.7-5.0)	4.6±0.4 (2.8-7.0)	4.3±0.2 (2.6-6.0)
3. Blood Urea (mmol/L)	19±3 (7-28)	14±2 (7-23)	22±3 (11-43)	19±2 (7-35)
4. Serum Creatinine (umol/L)	133±18 (71-221)	115±18 (44-177)	186±27 (88-398)	150±18 (71-318)
5. FENa%**	1.13±0.06 (0.85-1.34)	1.30±0.09* (1.04-1.65)	1.12±0.07 (0.96-1.34)	1.28±0.06* (1.06-1.42)

Mean ± SEM (range), * p < 0.001, ** IV group (n = 19), IO group (n = 15).

busy pediatric Emergency. However, it should not be routinely used in children needing parenteral fluids or drugs. Proficiency in securing the intraosseous route can be attained easily. In a study conducted by Siegler *et al*. (20) paramedics could successfully establish intraosseous line in 16 out of 17 cases after short periods of training. Similar studies(21,22) on insertion of intraosseous needle by paramedics showed success rate of 80-85% in first attempt and almost 100% with second attempt.

An important advantage of intraosseous route over intravenous route, as also evident from this study, is the rapidity with which it can be achieved. Kanter *et al.* (19) reported a median IV access time of 10 minutes (range 2-40 minutes). In contrast, intramedullary needle placement was achieved within 15 seconds in the study done by Brickman *et al.* (23), and in an average time of 27.5 seconds using a spinal needle and 11 seconds using a bone marrow needle in the experimental study by McCabe *et al.* (22). In the studies conducted in prehospital setting(20,21) paramedics usually took about a minute. In our study, the average time taken to obtain IO access was almost half the time required for successful IV cannulation.

The intravenous route is traditionally used for rapid fluid infusion. There is paucity of literature on the efficacy of IO route in correcting various hemodynamic parameters in patients with hypovolemia. We, however, found that fluid infusion through either of the routes was equally effective in stabilization of vital signs, correction of dehydration, acidosis, electrolyte disturbances and abnormal serum osmolality. The mean systolic blood.pressure rose from 58 ± 3 mm Hg (preinfusion) to 86 ± 2 mm Hg after 2 hours of infusion. This is in consonance with the experimental work of Velasco *et al.* (25) who found rapid rise in mean arterial pressure (from base line value of 15 mmHg to 65 mmHg after 2 hours) when fluid was infused through IO route in hypovolemic dogs. Neufeld *et al.* (26) also found no significant differences (as measured by mean arterial pressure changes, pulmonary capillary wedge pressure, cardiac output and mixed oxygen saturation) among central venous, IV and IO routes.

The fall in blood urea and serum creatinine and increase in fractional excretion of sodium with fluid infusion through either of these routes indicates that both the routes are effective in inducing diuresis, increasing glomerular filtration rate and expanding the intravascular volume. The greater fall in serum sodium in the IO group was probably due to higher mean sodium concentration at admission and more severe disturbance in water balance in these patients. Rate of fluid infusion through IO route (using 18G needle) in our study ranged from 1 ml/min-3 ml/min using a gravity drip. This rate was sufficient for the infusion of desired amounts of fluid. In an experimental study, Hodge *et al.* (24), using 20 G and 13 G needles found the flow rates to be 11 ml/min and 29 ml/min, respectively under pressure of 200 mm Hg.

No significant acute complications were noted with either IV or IO routes. It should be noted that no long term follow up was done in patients who received fluid through the IO rate as this was beyond the scope of the study. However, no overt iatrogenic complications have been brought to the notice of the investigators. One finds in older literature instances of various complications like cellulkis, periosteitis and osteomyelitis(27,28), problems which may be due to inadequate asepsis and use of the

IO route for fluid administration over prolonged periods of time. With the present concept of the use of IO route only during the initial resuscitation and rehydration, infectious complications do not find mention in the current literature. Our experience is also similar. No long lasting effects on bone, growth plate and marrow elements have been demonstrated in various clinical and experimental studies(29,30). Orlowski *et al*. (31) demonstrated a high incidence of fat emboli in experimental animals with IO infusion and there would be some risk of cerebral fat embolus in patients with patent foramen ovale. However, we did not encounter this complication in any of the cases who received IO infusion.

We, therefore, believe that the intraosseous route may be considered a reliable, safe and easily accessible route for fluid infusion in states of hypovolemia and peripheral vascular collapse.

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