Evaluation of the safety and efficacy of the central venous administration of potassium chloride including the measurement of intracardiac potassium concentrations

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ABSTRACT

This study examined the safety and efficacy of the intravenous administration of 20 mEq potassium chloride (KCl) dissolved in a 100 cc 5% dextrose in sterile water bolus over 1 hour through a subclavian central vein catheter in critical care unit patients for the treatment of low and low to normal serum potassium concentrations. We studied seven patients with morning serum potassium between 2.4 and 3.6 mEq/L who had intravenous KCl boluses ordered by their treating physician. Intracardiac and peripheral venous potassium levels were obtained before, during, and after infusion. Holter and electrocardiogram assessment of rhythm, supraventricular and ventricular ectopy, and electrical intervals were recorded before, during, and after the intravenous KCl bolus. The cardiac rhythm, heart rates, and electrocardiographic intervals remained unchanged throughout the infusion and postinfusion phases. In six of the seven patients, there was no new or worsening supraventricular or ventricular ectopy temporally related to the infusion. Postinfusion potassium levels increased in all patients, with an average peripheral vein serum potassium increase of 0.4 mEq/L. In conclusion, within the limitations of our sample size, our study demonstrated the safety and efficacy of the central venous infusion of 20 mEq KCl in 100 cc 5% dextrose in sterile water administered over 1 hour.

KEYWORDS Central administration of potassium; hypokalemia; intracardiac potassium; potassium infusion

Multiple conflicting recommendations exist regarding the administration of intravenous potassium chloride (KCl), particularly in the critical care setting, either for the treatment of overt hypokalemia or the prevention of hypokalemia when potassium is in the low to normal range. There is no consensus about the specific route of infusion, the potassium in the infusate, the type of diluent fluid, or the rate of administration. Some recommend that intravenous KCl boluses should only be administered via a central vein since administration via a peripheral route may be poorly tolerated and can result in phlebitis and pain.¹ UpToDate stated that “for patients with severe hypokalemia due to gastrointestinal or renal losses, the recommended maximum rate of potassium administration is 10–20 mEq/h in most patients. However, initial rates as high as 40 mEq/h have been used in life-threatening hypokalemia.^{2–5} Rates >20 mEq/h are highly irritating to peripheral veins. Such high

rates should be infused into a large central vein or into multiple peripheral veins.”⁶ However, others have raised concern that infusing high concentrations of potassium directly into a cardiac chamber, via a central line, may excessively elevate intracardiac potassium and potentially generate dangerous arrhythmias.⁷ Controversy also exists regarding the ideal carrier solution for the KCl bolus. The addition of KCl to normal saline generates a hypertonic solution. When KCl is dissolved in a dextrose-containing fluid such as 5% dextrose in sterile water (D5W), insulin-mediated shifts of potassium into cells could transiently worsen hypokalemia and potentially exacerbate cardiac arrhythmias. Currently, marked variability exists regarding intravenous KCl bolus replacement orders across different critical care facilities. This variability includes the amount of KCl (10, 20, and 40 mEq), its concentration (diluted in volumes between 100 and 250 mL), the carrier fluid (D5W or normal saline), and the intravenous route.

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Figure 1. Study design schematic illustrating periods of the potassium infusion and Holter monitoring and the temporal sequence of the electrocardiographic recordings and potassium samplings.

METHODS

The study was approved by the Baylor University Medical Center institutional review board. Informed consent was obtained from each patient. Seven patients were studied, five men and two women aged 58 to 76 years old with a weight range of 54 to 96 kg. Inclusion criteria required each patient to be in the critical care unit and to have a functioning triple-lumen central line catheter (placement verified by chest x-ray). Each patient had dedicated hemodynamic monitoring (Space labs, Snoqualmie,

Table 1. The temporal sequence of potassium levels by sampling location

Patient	Preinfusion potassium (mEq/L)	Min	Infusion potassium (mEq/L)			Postinfusion potassium (mEq/L)
			RA	PA	Systemic	
1	3.33	2	5.41	3.62	3.64	3.97
		10	5.44	3.75	3.72	
		30	5.59	4.07	3.99	
		50	5.87	4.30	4.20	
2	3.5	2	3.94	3.65	3.65	3.72
		10	3.89	3.69	3.70	
		30	3.80	3.77	3.73	
		50	4.00	3.75	3.72	
3	3.64	2	3.98	3.85	3.87	4.27
		10	4.30	4.03	4.06	
		30	4.88	4.30	4.28	
		50	5.02	4.57	4.41	
4	2.83	2	2.61	2.89	2.89	3.11
		10	2.69	3.05	3.05	
		30	2.87	3.08	3.17	
		50	2.96	3.12	3.23	
5	3.48	2	3.47	3.75	3.59	3.67
		10	3.52	3.87	3.71	
		30	4.19	3.93	3.80	
		50	4.59	3.95	3.91	
6	3.27	2	3.53	3.39	3.35	3.74
		10	3.76	3.57	3.54	
		30	3.94	3.82	3.78	
		50	4.31	4.01	3.98	
7	2.36	2	2.70	2.63	2.56	2.91
		10	2.82	2.71	2.68	
		30	3.18	3.00	2.91	
		50	3.35	3.08	3.00	

PA indicates pulmonary artery; RA, right atrial.

Table 2. Serum potassium levels, Holter rhythm analysis, electrocardiogram interval measurements, and changes in ectopy for central venous administration of potassium chloride

Patient	Serum K+ (mEq/L)		Δ K+ (mEq/L)	Study phase	Rhythm	Heart rate (beats/min)	EKG: Intervals (ms)			Ectopy (beats/h)	
	Pre	Post					PR	QRS	QTc	SVE	VE
1	3.33	3.97	+.64	Pre	NSR	65	148	84	425	4.8	0
				During	NSR	66	140	80	421	2.8	0
				Post	NSR	69	140	80	413	1.7	0
2	3.50	3.72	+.22	Pre	S. Tach	101	116	84	390	0	0
				During	S. Tach	107	120	80	400	0	0
				Post	S. Tach	107	112	84	400	0	0
3	3.64	4.27	+.63	Pre	NSR	96	124	84	395	0	0
				During	NSR	99	116	84	390	0	0
				Post	NSR	102	112	84	390	0	0
4	2.83	3.11	+.28	Pre	S. Tach	146	150	76	403	0	2.4
				During	S. Tach	139	136	84	400	1.7	0.8
				Post	S. Tach	132	128	88	469	0	0
5	3.48	3.67	+.19	Pre	S. Tach	114	124	88	481	0	0
				During	S. Tach	111	128	88	491	0	0
				Post	S. Tach	115	120	88	492	0	0
6	3.27	3.74	+.47	Pre	NSR	100	132	84	426	201	0
				During	NSR	100	128	72	420	51	0
				Post	NSR	100	128	80	395	44	0
7	2.36	2.91	+.55	Pre	NSR	62	172	108	406	0	90
				During	NSR	61	168	100	388	–	–
				Post	NSR	66	168	100	434	4	76

EKG indicates electrocardiogram; K, potassium; NSR, normal sinus rhythm; S. Tach: sinus tachycardia; SVE, supraventricular ectopy; VE, ventricular ectopy.

WA) with output Holter capability to record cardiac rhythms. The morning serum potassium was ≤ 3.6 mEq/L.

The study design is outlined in [Figure 1](#). A 12-lead electrocardiogram was performed preinfusion, midinfusion, and postinfusion. Continuous Holter monitoring was obtained throughout all three phases. The KCl infusion was administered via the most proximal port of the central line catheter. Blood was sampled distally from the right atrial port, the pulmonary artery port, and a peripheral arm vein. Sampling was obtained at 2, 10, 30, and 50 min during the potassium infusion. The postinfusion “systemic” potassium assessment was defined as the potassium in peripheral blood sampled 15 min following termination of the KCl bolus. Each central and peripheral venous sample was preceded by a 10 cc “bleed off” to minimize dilution errors. Potassium measurements were made as quickly as possible with a Beckman flame photometer (Beckman Coulter, Indianapolis, IN). For each sample, three analyses were

averaged, and all potassium measurements within each set were within 0.02 mEq/L.

RESULTS

[Table 1](#) shows the temporal sequence of the measured potassium concentrations by sampling location. During the infusion, the right atrial potassium increased slightly, but it approached 6 mEq/L only in a single patient (#1). Pulmonary artery and systemic potassium during all infusions remained ≤ 6 mEq/L and minimally increased. Patient 3 had the highest initial potassium (3.64 mEq/L) but did not develop an elevated right atrial potassium.

As shown in [Table 2](#), the cardiac rhythm, heart rates, and electrocardiographic intervals remained stable and unchanged during and after the infusions. The rate of supraventricular ectopy fell from 4.8 to 1.7 beats/h in patient 1 and from 201 to 44 beats/h in patient 6. Ventricular ectopy in Patients 4 and 7 fell from 2.4 to 0 beats/h and from 90 to 76 beats/h, respectively. Postinfusion peripheral potassium

increased in all patients, and the increase averaged 0.4 mEq/L.

DISCUSSION

Bolus potassium repletion (for either low-normal potassium levels or for overt hypokalemia) is most often infused into a peripheral vein at concentrations between 20 and 60 mEq/L either in D5W or a saline solution. Use of an infusion pump is recommended to prevent overly rapid potassium administration when a bolus of 40 mEq or more is ordered or if the desired rate of potassium administration is >10 mEq/h. Additionally, for patients with severe hypokalemia in the monitored setting, administration through a large central vein is generally preferred if this access is available.

There have been few published studies regarding the efficacy and safety of concentrated intravenous KCl infusions. Krouse et al⁸ retrospectively studied 1351 individual intravenous potassium infusions given to patients in the intensive care unit. Their analysis supported the “relative safety of using concentrated (200 mEq/L) potassium chloride infusions at a rate of 20 mEq/h via a central line or peripheral vein to correct hypokalemia.” Weaknesses of that study included its retrospective design, infrequent potassium measurements, and postinfusion systemic potassium determinations delayed up to 12 hours postinfusion in some patients. Hamill et al⁴ reported a prospective study of intravenous KCl infusions in an intensive care unit in 48 patients using concentrations of 20, 30, or 40 mmol KCl in 100 mL normal saline over 1 hour. Systemic serum potassium was measured pre- and postinfusion with a time separation of 4 hours. All patients tolerated the infusions without evidence of hemodynamic compromise or electrocardiographic changes. However, intracardiac chamber potassium was not measured and electrocardiographic changes were not monitored.

The current study utilized continuous monitoring of the cardiac rate, rhythm, and cardiac intervals. Intracardiac chamber potassium during the central venous infusion of KCl was monitored. Our findings indicate that concerns

raised about elevated intracardiac potassium and the generation of cardiac dysrhythmias were not substantiated. Within the limitations commensurate with the small sample size, this study supports the safety and efficacy of utilizing 20 mEq/L in 100 cc D5W via controlled infusion over 1 hour via a central venous catheter for the treatment of low and low-normal potassium.

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1. Stephen M, Loewenthal J, Wong J, et al. Complications of intravenous therapy. *Med J Aust.* 1976;2:557–559. doi:10.5694/j.1326-5377.1976.tb130386.x.
2. Rose BD, Post TW. Hypokalemia. In *Clinical Physiology of Acid-Base and Electrolyte Disorders*. 5th ed. New York: McGraw-Hill; 2001: 836–887.
3. Abramson E, Arky R. Diabetic acidosis with initial hypokalemia. Therapeutic implications. *JAMA.* 1966;196:401–405. doi:10.1001/jama.1966.03100180069021.
4. Hamill RJ, Robinson LM, Wexler HR, et al. Efficacy and safety of potassium infusion therapy in hypokalemic critically ill patients. *Crit Care Med.* 1991;19(5):694–699. doi:10.1097/00003246-199105000-00016.
5. Pullen H, Doig A, Lambie AT. Intensive intravenous potassium replacement therapy. *Lancet.* 1967;2(7520):809–811. doi:10.1016/S0140-6736(67)92239-8.
6. Mount DB. Clinical manifestations and treatment of hypokalemia in adults In: Post TW, ed. *UpToDate*. Waltham, MA: UpToDate Inc; 2019. <https://www.uptodate.com>. Accessed March 21, 2019.
7. Bia M, DeFronzo R. Intravenous potassium chloride therapy—reply. *JAMA.* 1981;245(23):2446. doi:10.1001/jama.1982.03320280026016.
8. Krouse JA, Carlson RW. Rapid correction of hypokalemia using concentrated intravenous potassium chloride infusions. *Arch Intern Med.* 1990;150:613–617. doi:10.1001/archinte.1990.00390150101019.