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## Portable Blood (Gas) Analyzer in a Helicopter Emergency Medical Service



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## A B S T R A C T

**Introduction:** In prehospital helicopter emergency medical services (HEMS), the medical team frequently manages critical patients with only limited, noninvasive monitoring options on-site and during HEMS transport. To gain deeper insight into the patient's pathology and to track prehospital treatment effects, a point-of-care blood (gas) analyzer appears desirable also in HEMS. Thus, we hypothesized that prehospital blood (gas) analysis is feasible in the HEMS setting.

**Methods:** A prehospital evaluation of a portable blood (gas) analyzer (i-Stat 1; Abbott, Chicago, IL) with appropriate laboratory cartridges was performed within the Dutch HEMS Lifeline 1, serving a region of ~4.5 million inhabitants. Venous blood (gas) measurements were performed in our HEMS collective in both trauma and nontrauma cases.

**Results:** The HEMS team identified benefits (eg, portability and speed) and limitations (eg, a narrow operational temperature range) regarding the tested blood (gas) analyzer. Regarding the actual blood (gas) results, the team collected results without major abnormalities but also cases identifying major pathologies, including several cases of marked acidosis, refractory hypoglycemia, or severe anemia.

**Conclusion:** In conclusion, portable blood (gas) analysis proved feasible in an HEMS operation but with relevant limitations. Future studies will have to show how these limitations can be overcome and how the implementation of portable blood (gas) analyzers may support improved patient outcome.

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In prehospital helicopter emergency medical services (HEMS), the medical team frequently manages critical patients with only limited, noninvasive monitoring options on-site and during transport. To allow deeper insight into the patient's pathology and to track prehospital treatment effects, it appears desirable to have point-of-care blood (gas) analysis (BGA) available in HEMS.<sup>1</sup>

Current developments in international HEMS organizations emphasize this requirement. Treatment options traditionally reserved for in-hospital therapy are increasingly performed on-site already,<sup>2</sup> including erythrocyte transfusions.<sup>3–5</sup> Herein, prehospital BGAs should support identifying patients requiring prehospital transfusion (eg, via the acid/base status) because hemodynamic parameters appear to be insufficient predictors.<sup>3</sup> In addition, national HEMS are extending the scope

from classic trauma indications to critically ill nontrauma patients. Also, prehospital BGA appears to be a valuable tool for diagnosis and tracking treatment effects.<sup>6</sup> We hypothesized that prehospital BGA is feasible in our HEMS setting and evaluated the prehospital usefulness of a portable BGA device for routine patient care.

### Methods

This prehospital evaluation was performed on the Dutch HEMS Lifeline 1, which serves a region with about 4.5 million inhabitants for treatment and transport of both severe trauma and nontrauma cases. Most commercial BGA analyzers are too bulky for prehospital HEMS use; therefore, market research was performed. By exploring the few portable BGA devices available, we identified the i-Stat 1 (Abbott, The Netherlands) as a promising candidate<sup>7</sup> suitable for prehospital application (23 × 8 × 7 cm, 650 g), although it is primarily designed for in-hospital use.<sup>8</sup> From the various types of blood laboratory cartridges available, the CG8+ (Abbott) was used. This CG8+

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cartridge type allows the simultaneous analysis of blood gases (PCO<sub>2</sub> and PO<sub>2</sub>), acid/base-related parameters (pH, base excess, TCO<sub>2</sub>, and HCO<sub>3</sub>), electrolytes (Na<sup>+</sup>, K<sup>+</sup>, and Ca<sup>++</sup>), hemoglobin, hematocrit, and glucose with 1 measurement of 95 μL blood.

Before implementation, testing for possible electromagnetic interactions between i-Stat and helicopter avionics (EC-135, Eurocopter and H-135, Airbus) did not show any abnormalities on ground or during flight. After these pretests, the BGA was introduced in our 24/7 HEMS operation, and the individual HEMS physician decided to use the analyzer on a per-patient basis. The applying physicians were interviewed afterward concerning their experiences. Given the heterogeneity of our HEMS population (eg, including both trauma and nontrauma cases), the actual blood (gas) results were not used for statistical analysis.

Within our hospital, the i-Stat 1 was already established and embedded in our laboratory's quality management system. This pre-hospital evaluation of an established clinical device does not fall under the Dutch Law on Medical Scientific Research Involving Human Beings (WMO), so formal approval from the institutional review board was not required.

**Results**

*System*

The HEMS physicians identified both benefits and limitations of the portable BGA analyzer. Beneficially, the HEMS physicians evaluated the analyzer as sufficiently portable (format and weight), sufficiently user-friendly, and fast enough concerning the measurement procedure.

The main restriction was the analyzer's limited operational ambient temperature range, from 16°C to 30°C. We tested the analyzer both in summer and winter months, exceeding the temperature limits in both directions. Outside this range, the analyzer did not accept new measurements.

Minor complaints concerned canceled BGA measurements (eg, because insufficient blood or an air bubble containing blood was injected into the BGA cartridge, necessitating repeat measurements). No needle accidents were reported, but loading the BGA cartridge with blood through a needle during flight or ground transport was reportedly challenging. Scanning of the cartridge's bar code from the paper package was hampered by transport movement artifacts or smearing of the bar code print on the paper package. No case of

disturbing scattering of the bar code scanner laser beam into the helicopter cockpit was reported.

*Sample Results*

This prehospital evaluation was limited to venous blood samples, either sampled via an intravenous catheter or by direct needle venipuncture. Although prehospital blood sampling can be challenging, this was not reported to be problematic for the ~100 μL blood required per BGA.

BGA results were exemplified for selected HEMS cases (n = 12), both for 6 trauma cases (Table 1) and 6 nontrauma cases (Table 2). Most patients had a loss of consciousness, and besides cases ruling out major BGA abnormalities, there were also cases with relevant BGA deviations, prompting additional interventions. Major pathologies identified by BGA were acidosis, with very low pH values (<7.0) found in cardiopulmonary resuscitation cases with sustained return of spontaneous circulation (ROSC) (ie, after a primary cardiac event [pH = 6.80], drug intoxication [pH = 6.80], and drowning [pH <6.50]). A very low hematocrit level (<15%) was measured in an exsanguinating multitrauma patient after crystalloid and mannitol infusion before prehospital blood transfusion. One case of unexpected refractory hypoglycemia (38 mg/dL, 2.1 mmol/L) was also detected.

**Discussion**

Prehospital BGA proved feasible in our HEMS; however, there were also several limitations identified. Our prehospital evaluation shows that the tested i-Stat system is sufficiently portable and ergonomic to perform BGA in the HEMS environment during flight or on scene. A main disadvantage of the i-Stat is the restricted operational ambient temperature range. To circumvent this, the device might be stored in an thermo-isolated casing.

The literature on point-of-care BGA in HEMS is limited. We only found 1 article on point-of-care measurement of blood chemistry (eg, glucose and electrolytes<sup>1</sup>) and no data on blood gas analysis in HEMS.

The tested i-Stat type is established within our hospital and thus embedded in our laboratory's quality management system. Therefore, it was not our goal to test the accuracy and reliability of the prehospital measurements; thus, we omitted cross-checking the prehospital BGA results with the hospital's reference laboratory system.

This evaluation was restricted to venous blood samples. Although arterial blood better reflects pulmonary function, venous blood should better reflect the tissue's state of perfusion and metabolism, even if marked heterogeneity may exist between sample sites (eg,

**Table 1**  
Prehospital Blood (Gas) Analysis of Selected Trauma Cases

	A1	A2	A3	A4	A5	A6
pH	7.296	7.412	7.333	<6.500	7.348	7.340
PCO <sub>2</sub> (mm Hg)	45.9	36.4	42.9	114.7	45.1	40.4
PO <sub>2</sub> (mm Hg)	31	79	114	163	46	159
SO <sub>2</sub> (%)	52	96	98	ND	79	99
BE (mmol/L)	-4	-1	-3	ND	-1	-4
HCO <sub>3</sub> (mmol/L)	22.4	23.2	22.8	ND	24.8	21.8
TCO <sub>2</sub> (mmol/L)	24	24	24	ND	26	23
Na <sup>+</sup> (mmol/L)	G3+	135	139	145	141	132
K <sup>+</sup> (mmol/L)	G3+	3.8	3.1	4.6	4.5	4.2
Ca <sup>++</sup> (mmol/L)	G3+	1.16	1.21	1.40	1.22	1.11
Glucose (mg/dL)	G3+	150	164	187	140	73
Hematocrit (%)	G3+	48	34	50	44	<15
Hemoglobin (g/dL)	G3+	16.3	11.6	17.0	15.0	ND
CPR	No	No	No	Yes, ROSC	No	No
Neurology	Intoxicated	LOC	Agitated	LOC	Awake	LOC
Trauma mechanism	Fall (stairs)	Fall (stairs)	Crash (bike)	Drowning (bike)	Fall (bike)	Fall (motorbike)

BE = base excess; CPR = cardiopulmonary resuscitation; GC3+ = analysis with the pure blood gas cartridge type GC3+; LOC = loss of consciousness; ND = not determined; ROSC = return of spontaneous circulation.

**Table 2**  
Prehospital Blood (Gas) Analysis of Selected Nontrauma Cases

	B1	B2	B3	B4	B5	B6
pH	6.980	7.184	6.981	7.375	7.323	7.516
PCO <sub>2</sub> (mm Hg)	82.7	58.7	99.5	46.4	59.2	31.3
PO <sub>2</sub> (mm Hg)	55	41	37	70	118	225
SO <sub>2</sub> (%)	67	63	42	93	98	100
BE (mmol/L)	-12	-6	-8	+2	+5	+2
HCO <sub>3</sub> (mmol/L)	19.5	22.1	23.5	27.1	30.7	25.4
TCO <sub>2</sub> (mmol/L)	22	24	26	29	33	26
Na <sup>+</sup> (mmol/L)	G3+	137	144	140	143	140
K <sup>+</sup> (mmol/L)	G3+	5.4	3.3	4.0	4.2	3.6
Ca <sup>++</sup> (mmol/L)	G3+	1.23	1.15	1.17	1.11	1.17
Glucose (mg/dL)	G3+	115	38	194	89	173
Hematocrit (%)	G3+	38	42	37	39	35
Hemoglobin (g/dL)	G3+	12.9	14.3	12.6	13.3	11.9
CPR	Yes, ROSC	Yes	Yes, ROSC	No	No	No
Neurology	LOC	LOC	LOC	LOC	LOC	LOC
Disease	Cardiac	Cardiac	Drugs	ICB	Epilepsy	ICB

BE = base excess; CPR = cardiopulmonary resuscitation; GC3+ = analysis with the pure blood gas cartridge type GC3+; ICB = intracranial bleeding; LOC = loss of consciousness; ND = not determined; ROSC = return of spontaneous circulation.



**Figure 1.** Example of a measurement with the i-Stat blood (gas) analyzer during HEMS flight. The gloved hand of the HEMS physician operating the i-Stat gives an indication of the dimensions of the device.

external jugular vein vs. antecubital vein).<sup>9</sup> In addition, venous blood sampling is far more practical in HEMS settings.

Prehospital BGA might add valuable information in resuscitation settings.<sup>10</sup> Despite the limited case number so far, our results show that otherwise inaccessible confounders of cardiac arrest (eg, electrolyte abnormalities) could be determined in the preclinical HEMS setting. In

addition, BGA may also help to detect the extent of derangement after ROSC (eg, pH or negative base excess) and guide subsequent resuscitative therapy.

Recently, we introduced prehospital erythrocyte transfusions in our HEMS. To rationalize individual transfusions, we currently explore BGA-derived hematocrit and acid/base-related parameters as an additional transfusion trigger because systemic hemodynamics alone appear to be insufficient discriminators.<sup>3</sup> We show that preclinical determination of these parameters is practical, including an illustrative example of a hemorrhaged and crystalloid- and mannitol-resuscitated patient. However, further studies need to show how transfusion can be aided by BGA.

This prehospital evaluation was restricted to only 1 model of portable blood gas analyzers. Thus, we cannot judge the suitability of other portable BGA devices in the HEMS setting. The heterogeneity of our HEMS population (eg, covering both trauma and nontrauma cases) and, thus, the relatively small subgroup sizes did not support a meaningful statistical analysis of the actual BGA results.

In conclusion, prehospital BGA analysis proved feasible in the HEMS setting, despite limitations herein. Future experience and studies will have to show how portable blood gas analyzers may ultimately help to improve patient outcome.

## References

- Herr DM, Newton NC, Santrach PJ, Hankins DG, Burritt MF. Airborne and rescue point-of-care testing. *Am J Clin Pathol.* 1995;104(suppl 1):S54–S58.
- Schober P, de Leeuw MA, Terra M, Loer SA, Schwarte LA. Emergency clamshell thoracotomy in blunt trauma resuscitation: shelling the paradigm-2 cases and review of the literature. *Clin Case Rep.* 2018;6:1521–1524.
- Mix FM, Zielinski MD, Myers LA, et al. Prehospital blood product administration opportunities in ground transport ALS EMS—a descriptive study. *Prehosp Disaster Med.* 2018;33:230–236.
- Maher P, Utarnachitt R, Louzon MJ, Gary R, Sen N, Hess JR. Logistical concerns for prehospital blood product use by air medical services. *Air Med J.* 2017;36:263–267.
- Karl A, Pham T, Yanosky JD, Lubin J. Variability of uncrossmatched blood use by helicopter EMS programs in the United States. *Prehosp Emerg Care.* 2016;20:688–694.
- Zavadsky M, Partain D. Beyond blood sugar. *JEMS.* 2016;41:59–61.
- Pidetcha P, Ornvichian S, Chalachiva S. Accuracy and precision of the i-STAT portable clinical analyzer: an analytical point of view. *J Med Assoc Thai.* 2000;83:445–450.
- Prause G, Kaltenbock F, Doppler R. [Preclinical blood gas analysis. 2. Experience with three blood gas analyzers in emergency care]. *Anaesthesist.* 1998;47:490–495.
- Schober P, Schwarte LA. From system to organ to cell: oxygenation and perfusion measurement in anesthesia and critical care. *J Clin Monit Comput.* 2012;26:255–265.
- Prause G, Ratzenhofer-Comenda B, Smolle-Juttner F, et al. Comparison of lactate or BE during out-of-hospital cardiac arrest to determine metabolic acidosis. *Resuscitation.* 2001;51:297–300.