Commentary
Quantitative physico-chemical analysis of the acidosis of cardiac arrest
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Abstract
Metabolic acidosis is a common finding after cardiac arrest. Until recently this acidosis was mainly attributed to lactate. The physico-chemical approach to acid–base balance permits the detection of previously unmeasured ions. These ions have been shown to affect the acid–base status of patients.

Introduction
The acid–base disturbance in patients suffering cardiac arrest is more complex than previously thought. Makino and colleagues have presented a quantitative assessment of the components that create the disturbance [1]. As previously reported, hyperlactatemia is not the sole cause of metabolic acidosis in the patient after arrest [2]. The physico-chemical approach permits the detection of unmeasured ions and the measurement of their effect on the patient.

The physico-chemical approach
The authors present a concise review of the physico-chemical approach to acid–base balance using the Stewart–Figge methodology [3,4]. This concept is based on the principles of electric neutrality and the conservation of mass. There are three independent variables that determine blood pH: partial pressure of CO_2 (p_{CO_2}), total weak acid concentration (A_{TOT}) and the strong ion difference (SID). p_{CO_2} is an independent variable. Ions that are fully dissociated at physiologic pH are known as strong ions. The difference between the strong cations, such as sodium, and the strong anions, such as chloride, is SID. Weak acids (A_{TOT}) also carry a charge; these are principally albumin and phosphate. In keeping with the principles of electric neutrality, the difference between the charges will be zero unless there are unmeasured ions present. This difference is known as the strong ion gap (SIG). A more in-depth review and an Excel-based macro program can be found at The Acid Base pHorum [5].

The study
Makino and colleagues performed their prospective observational study in Japan. In that country there is no pre-hospital administration of medication. Blood samples were drawn on arrival before any iatrogenic manipulation. This allows a relatively rare opportunity to collect and study unaltered human cardiac arrest data. The authors comment that some intravenous fluid might have been started immediately before blood draw. Saline-based intravenous fluids are well known to create an acid–base disturbance, in particular a nongap hyperchloremic metabolic acidosis [6–8]. The fluid used during resuscitation was Ringer-based, which has a much smaller effect on the acid–base balance.

The comparison group was composed of 28 patients who suffered minor injuries and were discharged within 2 days. This group was chosen because all of the necessary blood samples were drawn on arrival. Given their minor injuries and short hospitalization, they were considered to be baseline 'normal'. The authors do comment on the fact that the comparison group initially had a mildly elevated lactate level. However, all other variables in the comparison group were normal. Although not optimal, that, in combination with the large difference in lactate between the study and comparison groups, does permit an adequate comparison.

This study had only a small number of patients enrolled. The patients suffered cardiac arrest from a variety of causes, both from physiologic disease and from trauma. Presumably because of the small number of patients enrolled they did not evaluate differences between the groups. Twelve percent of the patients are listed as 'other' for the cause of their cardiac arrest. This is the same proportion of patients who suffered cardiac arrest from trauma. This group of unknowns can certainly skew the results. For example, perhaps this group

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A_{TOT} = total weak acid concentration; p_{CO_2} = partial pressure of CO_2; SID = strong ion difference; SIG = strong ion gap.

ingested toxic alcohols, which would lead to severe metabolic acidosis. If this group had been evaluated separately, it might have led to a different outcome.

Only 10% of the patients had witnessed arrest. It is not surprising that the initial rhythm in more than 50% of the study patients was asystole. Nineteen percent of the arrest group had a return of spontaneous circulation. Unfortunately the authors did not comment on the outcome data for this group. What was the duration of survival? Obviously the numbers are small, only 20 patients. It would be interesting to know whether there was any trend or difference between survivors and nonsurvivors. In a study on vascular injury patients, a SIG of more than 5 was shown to be a marker for mortality [9].

Unmeasured ions

Unmeasured ions determined only by using the SID/SIG methodology have been discovered in a variety of patients: critically ill [10], trauma [11,12], pediatric [13] and now after cardiac arrest [1]. Recently Martin and colleagues reviewed data from more than 400 patients from their trauma intensive care unit [12]. Unmeasured ions were found in 92% of patients and were the most common component of metabolic acidosis in these patients. More importantly, 28% of patients had a different clinical interpretation and would have received different therapy if the physico-chemical approach had been used rather than the standard method that was used.

Conclusion

The acid–base derangement in the post-arrest victim is complex. Previously unrecognized factors contribute to the metabolic acidosis in equal amounts to that of lactate. The presence of unmeasured ions alters the clinical interpretation and treatment of the patient. This study has identified another area that needs further investigation to determine the significance of the presence of unmeasured ions in the post-arrest patient.

Competing interests

The author(s) declare that they have no competing interests.

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