Point of care testing: improving pediatric outcomes

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Abstract

Objective: Goal-directed therapy (GDT) has been proven to reduce morbidity and mortality in critical illness. Point of care testing (POCT) allows rapid turn around time (TAT) of critical data, yet data suggesting improved outcomes are very limited. The impact of these two strategies on improving outcomes for patients after congenital heart surgery has never been evaluated.

Design: Beginning July 2001, POCT in the form of the i-STAT handheld analyzer was incorporated in the management of patients after congenital heart surgery at our institution. Blood lactate measurements were performed serially for 24 h after surgery. Based on a lactate value, medical therapy was escalated, diminished or left unchanged after surgery. Outcome data were collected prospectively for later review. Mortality at 30 days after surgery was compared for patients undergoing a GDT protocol to a group of historical cohorts. The operative risk for all operations was determined using the RACHS-1 scoring system.

Setting: A 16-bed Cardiac Intensive Care Unit (CICU) in a 268-bed free-standing pediatric hospital.

Patients: Outcomes of infants and neonates operated on from July 2001 through July 2003 (Group B) were compared to historical controls in our institution from June 1995 through June 2001 (Group A). There were 851 patients in Group A and 378 patients in Group B. Patients in Group B were smaller and younger than those in group A (median weight 3.8 vs. 4.3 kg, P < 0.001; median age 42 vs. 76 days, P = 0.02).

Measurements and results: Overall mortality was lower for Group B as compared to Group A (2.4% vs. 6.2%, P < 0.007). Significant reduction in mortality between Group B and Group A was noted in neonates (4.3% vs. 12%, P = 0.008) but did not reach significance in infants (0.9% vs. 2.6%, P = NS). Patients undergoing the highest-risk operations (RACHS-1 groups 5 + 6) had a 70% reduction in mortality when comparing Group B to Group A, (9% vs. 30%, P = 0.03), but no statistical difference in mortality was noted in those patients undergoing lower-risk operations (RACHS-1 groups 1 and 2, Group B 0.5% vs. Group A 1.5%, P = NS).

Conclusions: The combination of goal-directed therapy and point of care testing significantly reduced mortality in patients undergoing congenital heart surgery. This improvement is greatest in the youngest patients and those undergoing higher-risk surgeries.

Keywords: Goal-directed therapy; Neonates; Point of care

Introduction

Point of care testing (POCT) or near patient testing typically refers to any laboratory test of any complexity, performed outside the central laboratory by non-laboratory personnel [1]. Obvious differences exist in the care rendered to a patient in a general ward or out patient setting as opposed to a critical care unit [2]. Decision making for patients in a hospital ward or outpatient setting is usually nonurgent in nature. Treatments can be delayed for hours or even days without untoward effects from the delay in management. In the critical care unit, life-threatening processes often require decision making in minutes, not hours. The critical care unit provides a unique environment that should take full advantage of the potential of POCT, yet despite the availability of numerous POCT devices, little data support the almost intuitive perception that POCT would improve outcomes in the critically ill.

The commitment of laboratory services to meet the changing needs of clinicians is longstanding. The development of critical care areas in hospitals began in the 1950s as an effort to centralize patients who required respiratory therapy as a consequence of poliomyelitis.

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The term intensive care unit was coined by Peter Safar at Baltimore City Hospital in 1958 [3]. From 1960 onward, the number of critical care units internationally exploded. Critically ill patients were noted to have unique demands, and as the understanding of critical care physiology grew, so did the demand on traditional laboratory services. Unique to the critically ill patient is a pathophysiological state that is rapidly changing or evolving. Also, medical management of these patients may have rapid untoward consequences if inappropriately administered or monitored. Clinicians must therefore respond to these changes quickly and appropriately [4].

To meet the demands imposed by newly developed critical care units, hospital laboratories developed batched tests that could be performed in central laboratories with a more rapid turn around time (TAT) than traditional laboratory tests. These so-called “STAT” tests became invaluable to clinicians. As the need to perform these tests continued to increase, STAT laboratories were developed. These STAT labs offered a limited number of tests, which were determined crucial for patient outcome, and were usually closely located to high demand areas such as critical care units, operating rooms or emergency departments.

Advances in microprocessor technology have allowed small devices (even handheld) to perform many of the critical laboratory tests performed in STAT labs. Arterial blood gas analysis, electrolytes, glucose and a myriad of other tests can be performed at the patient’s bedside with a blood gas analyzer, was chosen for several reasons. First, it was extremely portable and could easily be transferred from room to room in the CICU. Second, it was the only point of care device offering whole blood lactate measurements in the United States at that time. We believed the combination of a rapid TAT and serial blood lactate measurements would allow us to devise a clinical strategy for managing children after heart surgery that would result in improved outcomes.

Patients and methods

Patients

Patients included all patients undergoing congenital heart surgery in a 268-bed free-standing children’s hospital from June 1995 through July 2003. Patients were recovered in a 16-bed cardiac intensive care unit. Care was rendered by a multidisciplinary cardiovascular team consisting of attending board certified pediatric cardiologists, pediatric intensivists, neonatologists, physician assistants and nurses.

Study design

Near patient testing in the form of a POC device, the I-STAT™ analyzer (Abbott™) was introduced to the Cardiac Intensive Care Unit (CICU) in July of 2001. The I-STAT™ analyzer is a handheld device that uses different cartridges to do various lab tests. Each cartridge can run several tests and takes 120 s to report the results. The lactate cartridge (CG4) also measures $pO_2$, $pCO_2$ and pH. The patients ID and the nurse’s ID are directly scanned (using an integrated bar code scanner) into the I-STAT analyzer; 0.2 ml of blood is instilled into the cartridge and then the cartridge is inserted into the analyzer. Then, the result is displayed on the analyzer’s screen, printed out and reviewed by the CICU team members. The analyzer is then placed in a docking station where the results are transferred by wireless infrared communication to the hospital laboratory’s information system.

The I-STAT™ analyzer self-calibrates every 8 h via an electronic internal stimulator. In addition, the device is calibrated with the insertion of each individual cartridge. The central laboratory will also test each lot of purchased cartridges with an aqueous quality control ampule. Cartridges are stored in both the central laboratory and the cardiac intensive care unit in a storage refrigerator within the range of 2–8°C. Cartridges are also kept at an individual patient’s bedside, stored at room temperature, for not more than 1 week. The accuracy of the I-STAT™ lactate analysis was determined at the onset of the study with the simultaneous measurement of lactate via the POCT device and the central laboratory’s lactate analyzer (Beckman LX 20, Diamond Diagnostics, Holliston, MA) for 40 consecutive samples.

From July 2001 through June 2003, serial arterial blood lactate levels were measured in all postoperative patients. An algorithm was developed to direct physician response to changing lactate levels (Fig. 1). Medical management of patients wasescalated if the arterial blood lactate was rising or was failing to decrease at a rate of 0.5 mmol/l per hour. Arterial blood lactate was measured serially during the acute postoperative period in all patients. Routine measurement of blood lactate was discontinued when the blood lactate level was in the normal range. In neonates (patients less than 31 days of age at the time of surgery), blood lactate was measured hourly for the first 4–6 h after admission to the CICU. Neonates had more frequent lactate monitoring because mortality for neonatal congenital heart operations is much greater than for any other age group. For all other patients, lactate was measured serially every 4–6 h. If the lactate level was less than 5 mmol/l or if the lactate trend was acceptable (decrease of more than 0.5 mmol/l per hour), lactate was then measured every 4–6 h until normal (~<2.2 mmol/l for the purpose of our study). The reference value for arterial blood lactate is 0.36–1.25 mmol/l for the I-STAT™ analyzer. The frequency of serial lactate monitoring could be increased at the
physician discretion if they believed the clinical situation warranted it.

The same cardiovascular surgeon performed the majority (70%) of the operations described in this study. Outcome data for patients included in this study were collected prospectively for later review. Outcome data were collected and stored utilizing the CardioAccess™ database (CardioAccess Fort Lauderdale, Fl).

The study patients were divided into two groups; those infants and neonates who had undergone cardiac surgery from June 1995 to June 2001, before the implementation of the GDT protocol utilizing lactate, were included in Group A (pre i-STAT), while Group B, the GDT group, was composed of infants and neonates undergoing cardiac surgery from July 2001 to June 2003 (post i-STAT).

The operative risk for all patients undergoing heart surgery was determined according to the RACHS-1 (Risk Adjustment for Congenital Heart Surgery) scoring system [5]. RACHS-1 scoring was devised to categorize the risk for death associated with various congenital heart operations. RACHS-1 divides the surgeries into six categories, with category 1 being the simplest surgeries with the lowest mortality and category 6 being the surgeries with the highest mortality.

Statistical analysis was performed using Sigma Stat for Windows Version 2.03, SPSS Inc (Chicago, IL). Chi-square analysis was used to detected differences in mortality between groups. Mann–Whitney rank sum analysis was used to determine differences in demographic data between groups.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Pre i-STAT</th>
<th>i-STAT</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>851</td>
<td>378</td>
<td></td>
</tr>
<tr>
<td>Neonates</td>
<td>320</td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>Infants</td>
<td>531</td>
<td>214</td>
<td></td>
</tr>
<tr>
<td>Median weight (kg)</td>
<td>4.3</td>
<td>3.85</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Median age (days)</td>
<td>76</td>
<td>42</td>
<td>0.02</td>
</tr>
<tr>
<td>RACHS (mean)</td>
<td>2.67</td>
<td>2.78</td>
<td>NS</td>
</tr>
</tbody>
</table>

Result

There were a total of 851 patients in Group A (June 1995–June 2001) and 378 in Group B (July 2001–June 2003). Patient demographics are demonstrated in (Table 1). Patients in Group B were significantly younger and smaller. RACHS-1 scores were similar between groups (Table 1). Patients in Group B had significantly longer cardiopulmonary bypass times and aortic cross-clamp times (Fig. 2).

Fig. 3 demonstrates mortality for patients undergoing surgery in Groups A and B and also in the 24-month period immediately preceding the introduction of the i-STAT technology. Mortality for all patients in Group B was lower than that for patients in Group A (2.4% vs. 6.2%, $P < 0.007$). Infant mortality was reduced by 2/3 but did not reach statistical significance. Neonatal mortality was significantly decreased for patients in group B. When comparing mortality of group B patients with patients operated on in the 24 months preceding i-STAT, significant reductions in mortality were noted for all patients under 1 year and for neonates.

The patients were also grouped according to the complexity of the surgery performed (RACHS-1 scores). This is
demonstrated in Fig. 4. Since the number of patients is small, for statistical analysis, the patients in RACHS-1 categories 1 and 2, 3 and 4, and 5 and 6 were grouped together. For patients in the lower-risk RACHS groups 1 and 2, there is no difference in mortality between Groups A and B. However, in RACHS groups 3 and 4 and in groups 5 and 6, Group B has significantly lower mortality than Group A.

Discussion

In July of 2001, the I-STAT™ blood gas analyzer was introduced to the CICU at Miami Children’s Hospital. The i-Stat was intended to replace most of the functions provided by our “STAT lab”, and allows us to measure blood lactate levels with a rapid TAT. The decision to incorporate the i-Stat into our routine practice was based on the following premise. First, we wanted to establish a practice that incorporated near patient testing associated with the shortest possible TAT of essential laboratory data for managing patients after heart surgery. Our belief was that this would allow the clinician to react quickly to changing physiologic conditions. With the addition of i-Stat, our critical laboratory results would now be available within 120 s. Second, we elected to establish lactate as an objective indicator of oxygen debt. We then sought to establish clinical guidelines directed at normalizing blood lactate levels, thereby minimizing oxygen debt. We believed that utilizing this combination in clinical practice would improve survival for patients undergoing congenital heart surgery.

Before the availability of POCT testing, it would not have been possible to implement a GDT module at our institution since the TAT for lactate laboratory results was prohibitively long at times (ranging 15 min to 2 h) and would have made it impractical to base minute-to-minute decisions on changes in blood lactate levels. It should be noted that lactate values were measured during the earlier era in our main hospital laboratory and were not available from our STAT lab.

POCT has expanded rapidly in the last few years, much faster than the growth of the central laboratory [6]. As technology improved, smaller portable instruments have been developed to perform multiple tests accurately and in a short amount of time, while requiring minimal or no calibration [7–9]. While POCT has shown to indirectly affect outcome in disease states such as diabetes [8], improvement in outcomes has not been shown in critical care areas. This despite the intuitive notion that rapid TATs associated with near patient testing devices, such as the i-Stat analyzer, should allow clinicians to make critical decisions in patients with rapidly developing clinical problems more promptly.

This use of lactate as an end point of resuscitation in this study is not novel [9]. With the availability of POCT in July of 2001, we decided lactate might be the ideal treatment end point of resuscitation in our patient population. Lactate is a byproduct of glycolysis. Without oxygen, pyruvate is unable to enter the Krebs cycle and is transformed into lactate to maintain ATP production. Lactate has repeatedly shown to predict morbidity and mortality in critical illness, including patients undergoing congenital heart surgery [10–16].

Moderate to severe elevation in lactate in patients following congenital heart surgery is most likely related to inadequate tissue oxygen delivery, complicated by liver and renal dysfunction (the organs primarily responsible for the metabolism of lactate). Improving tissue oxygen delivery in this population may therefore diminish the production of lactate and increase the metabolism of lactate (by improving both renal and hepatic function). Patients recovering from congenital heart surgery are noted to have evidence of
inadequate oxygen delivery that usually resolves within 24 h of surgery in survivors [16–19]. Estimating the adequacy of oxygen delivery in this patient population remains difficult. Intracardiac shunting and small patient size makes techniques such as mixed venous oxygen saturation monitoring or thermodilution cardiac output monitoring difficult if not impossible for many patients. Blood lactate sampling becomes an excellent, noninvasive indicator of adequate tissue oxygen delivery.

The efficacy of GDT has been the subject of numerous clinical and experimental studies along with meta-analysis [20–24]. In 1988, Shoemaker et al. [20] showed that therapy aimed at increasing indices of oxygen delivery in high-risk surgical patients to values noted in survivors could result in reduced morbidity and mortality. Later, in a study of adult patients recovering from heart surgery, a protocol aimed at maintaining a mixed venous oxygen saturation of 70% and a lactate level of 2 mmol/l or less resulted in shorter hospital stays and fewer postoperative complications [21].

The introduction of the i-STAT blood gas analyzer along with the clinical algorithm for GDT to normalize arterial blood lactate resulted in a marked reduction in mortality for patients undergoing heart surgery in our institution. Reduction in mortality after surgery was a striking 2/3 for all patients under 1 year of age and 70% for those less than 1 month. Even more impressive, patients undergoing congenital heart surgery utilizing the GDT approach were at much higher risk of dying than patients in the previous era as indicated by their smaller size, younger age, and longer cardiopulmonary bypass and aortic cross-clamp times (suggesting more complex operations). It was clear that the greatest reductions in mortality had occurred in the youngest and highest-risk patients undergoing surgery (those with RACHS-1 scores greater than 3). What is less clear is whether the POCT device or the algorithm directed at normalizing blood lactate was most responsible for the reduction in mortality. At our institution, a patient management algorithm based on serial lactate measurements was only made possible with the introduction of the i-STAT blood gas analyzer. Before this, TAT for testing blood lactate was considered prolonged (often greater than 1 h). It is possible that a similar reduction in mortality might be achieved without a POCT device, in a system that allowed for extremely rapid TATs of a variety of critical lab tests including blood gas analysis and blood lactate measurement.

It is unlikely that any such system could equal the TAT associated with a device such as the i-STAT. Since blood lactate can change rapidly (within minutes) under adverse conditions or period of recovery [25], a TAT of longer than a few minutes for the evaluation of blood lactate in the critically ill is probably less than optimal.

Potentially, the management strategy outlined in this study could be applied to other populations of critically ill patients. It is reasonable to assume that patients with pathological processes similar to patients undergoing congenital heart surgery would be most likely to benefit from the combination of GDT (with lactate as an end point of resuscitation) and POCT (for rapid TAT of serial blood lactate measurements). Similar patient populations would be those patients who most likely have hyperlactatemia as a consequence of diminished tissue perfusion or end organ dysfunction (hepatic and renal) secondary to decreased oxygen delivery, such as patients recovering from major trauma or high-risk surgery [14,26]. These patients would most likely benefit from prompt recognition of tissue dysoxia and timely restoration of appropriate oxygen delivery. It is somewhat less clear why patients who develop elevated blood lactate levels secondary to more complex metabolic processes, such as the patients with septic, would benefit from an increase in oxygen delivery, but it is fairly conclusive that optimizing oxygen delivery even in this group of patients can markedly reduce mortality [23,24].

Conclusions

The introduction of a POCT device, which provides rapid TAT of blood lactate, into a pediatric cardiac intensive care unit coupled with the development of a management protocol based on serial analysis of arterial blood lactate resulted in a marked improvement in outcomes for infant and neonates undergoing heart surgery. The remarkable reduction in mortality noted here suggests this treatment strategy warrants further study in this population and other populations of critically ill patients. The reduction in mortality was achieved at no risk to the patient. The TAT for lactate in our study was 120 s. The upper limit of TAT for blood lactate to reproduce our results remains to be determined.

References


