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SHORT COMMUNICATION

# A portable blood analyzer that uses on-line data management to deliver higher-quality patient information

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**Abstract** We constructed an on-line data management system and linked it to the communication protocol of a portable blood analyzer (i-STAT) in each operating room of our institution. We developed a new program that integrates circulatory dynamics data from a monitor with laboratory data from the i-STAT. Our new program permits the results to be viewed through an intranet using a novel prototype communication device for the i-STAT 300F. We verified that this system can improve the quality of patient care both bedside and in the monitoring room and compared the costs of blood testing using a conventional desktop blood-gas analyzer and using the i-STAT. We found that the novel integration of circulatory dynamics with laboratory data enhanced the quality of intraoperative patient monitoring and reduced the cost and work load of doctors working in the operating room.

**Keywords** On-line data management system · Blood analyzer · i-STAT · Point of care

When treating operative patients in critical condition, laboratory data should be available in real time and at the patient's point of care (POC). In addition, the patient's data, including circulatory dynamics and laboratory data, need to satisfy information technology requirements so that results can be transmitted to the server computer and be stored in the patient's electronic medical record. In our institution, we monitor laboratory data of patients in the operating room using a portable blood analyzer (i-STAT 300F; Fuso Pharmaceutical Industries Ltd.) and record data using an on-line data management protocol. Supervisors then check these data in a central monitoring room. Although we could send laboratory data analyzed using an i-STAT [1, 2], which is a POC testing device, to a more powerful computer system, circulatory dynamics and laboratory data were analyzed separately. Historically, we sent laboratory data analyzed by the i-STAT in each operating room to computers using the RS-232C protocol. The receiving computer, which is the information monitoring system for the i-STATs, was referred to as the central data station (CDS); one CDS could receive data simultaneously from up to seven i-STATs. Our institution has 12 operating rooms, which required two CDSs [3]. With the previous system, attending anesthesiologists and supervisors had to check the time series of circulatory dynamics and laboratory test results on different computers. Both supervisors and attending anesthesiologists required more convenient data management methods. The purpose of this study was to develop a system that directly connects each i-STAT to a monitoring device and integrates data on circulatory dynamics and blood analysis.

We developed a novel system by connecting a downloader and a Unity ID (GE Yokogawa Medical Systems) to an i-STAT and the monitoring device via a serial communication protocol. Because the monitoring device is connected to a more powerful computer system, laboratory data analyzed by the i-STAT are transferred to the central monitoring room where supervisors can scrutinize them. During this transfer process, the Unity ID adds a timestamp to the data. Our novel data-handling software then allows supervisors to simultaneously scrutinize laboratory data with overlapping trend graphs and circulatory dynamics in

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**Table 1** Comparison of costs of blood analysis using a desktop analyzer and i-STAT

| Analyzer's name | ABL835 FLEX | | | | | i-STAT | | | |
|---|---|---|---|---|---|---|---|---|---|
| Quantity | 2 | | | | | 8 | | 12 | |
| Maintenance cost/month[a] | ¥917,500 | | | | | ¥333,333 | | ¥500,000 | |
| Sample transportation time | | 10 min | | 15 min | | 0 min | | 0 min | |
| Testing volume/month | Supplies cost | Transportation cost[b] | Total cost/month | Transportation cost[b] | Total cost/month | Supplies cost | Total cost/month | Supplies cost | Total cost/month |
| 150 | ¥543,390 | ¥75,000 | ¥1,535,890 | ¥112,500 | ¥1,573,390 | ¥264,000 | ¥597,333 | ¥264,000 | ¥764,000 |
| 300 | ¥555,694 | ¥150,000 | ¥1,623,194 | ¥225,000 | ¥1,698,194 | ¥528,000 | ¥861,333 | ¥528,000 | ¥1,028,000 |
| 450 | ¥567,998 | ¥225,000 | ¥1,710,498 | ¥337,500 | ¥1,822,998 | ¥792,000 | ¥1,125,333 | ¥792,000 | ¥1,292,000 |
| 600 | ¥580,302 | ¥300,000 | ¥1,797,802 | ¥450,000 | ¥1,947,802 | ¥1,056,000 | ¥1,389,333 | ¥1,056,000 | ¥1,556,000 |
| 750 | ¥593,000 | ¥375,000 | ¥1,885,500 | ¥562,500 | ¥2,073,000 | ¥1,320,000 | ¥1,653,333 | ¥1,320,000 | ¥1,820,000 |
| 900 | ¥605,698 | ¥450,000 | ¥1,973,198 | ¥675,000 | ¥2,198,198 | ¥1,584,000 | ¥1,917,333 | ¥1,584,000 | ¥2,084,000 |
| 1,200 | ¥630,356 | ¥600,000 | ¥2,147,856 | ¥900,000 | ¥2,447,856 | ¥2,112,000 | ¥2,445,333 | ¥2,112,000 | ¥2,612,000 |

Estimates are based on our institution. Sample transportation time is the time from calling the anesthesiologist for blood analysis to the time when the results are obtained in the operating room (OR). In the case of i-STAT, we can perform blood analysis in the OR by ourselves; that is, it is a point-of-care system

[a] Depreciation cost + maintenance fee

[b] Labor cost for sample transportation time

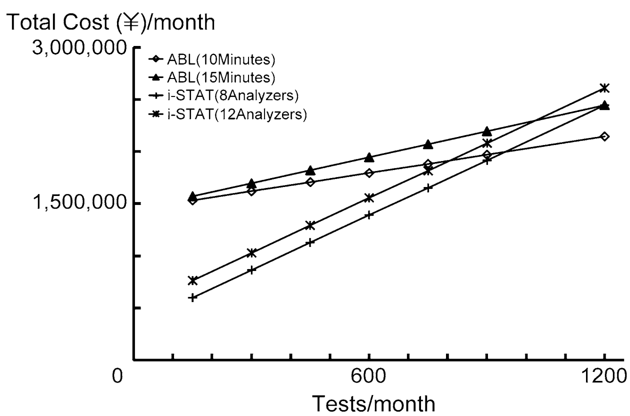


**Fig. 1** Monthly cost as a function of testing volume. The *X* axis indicates monthly testing volume and the *Y* axis indicates the monthly cost

the central monitoring room, thus enabling improved collective patient management.

With the new system, computers that receive the laboratory data (CDS) are no longer required, as the conditions under which blood samples are collected can be clarified and the circulatory dynamics data from patients can be integrated. Furthermore, the server computer automatically sends these integrated data to the computers in the individual operating rooms, where attending anesthesiologists can view records of both circulatory dynamics and analyzed data on a single display. Various parameters can be measured by changing the i-STAT cartridges. In our institution, by using CG8+ cartridges, we can directly measure the levels of glucose, sodium, potassium, ionized calcium, hematocrit, pH, carbon dioxide, and oxygen in whole blood and can calculate the levels of hemoglobin, ionized bicarbonate, total carbon dioxide, base excess, and oxygen saturation. Thus, this novel system has the advantage that patient information can be collectively managed using a monitor placed close to the patient by the attending anesthesiologists. This enables them to spend more time on patient care. In addition, electronic anesthesia records can be efficiently obtained. Connecting our system with electronic clinical records enables the patient status to be monitored through any terminal in the hospital, enhancing patient management.

The operating rooms at our institution contain various monitors, including bispectral index, neuromuscular transmission, and invasive and minimally invasive continuous cardiac output monitors. Integrating data obtained from these monitors with circulatory dynamics will improve perioperative patient management. For example, the effect of neuromuscular relaxants on patients with myasthenia gravis or cirrhosis might be more prolonged than on other patients. By integrating data obtained from a neuromuscular transmission monitor with this system, a supervisor will be able to direct the dosage of neuromuscular relaxants to attending anesthesiologists even from a central monitoring room. The fraction of inspired oxygen ($FIO_2$), which is critical for accurately evaluating patient status, can be monitored in the operating room. Our system allows simultaneous monitoring of $FIO_2$ and blood gas data, and the developed software integrates information from the monitoring device, such as heart rate, blood pressure, $FIO_2$, and electrocardiographic (ECG) waves, with laboratory data, making it far more informative. For example, we have recorded ECG waves, enabling patient information containing these and laboratory data from i-STAT to be evaluated retrospectively. Thus, monitoring the patient's information by attending anesthesiologists and supervisors will enable critical conditions to be detected faster and more accurately, enhancing patient safety.

Further, we calculated and compared the costs of blood testing using a conventional desktop blood analyzer (ABL; Radiometer Medical, Denmark) and using an i-STAT. We considered all possible costs, including the price of the apparatus, depreciation cost, labor costs of the anesthesiologist for transporting samples, and supply costs. Sample transportation time is the time from calling an anesthesiologist for testing to the time that test results are obtained. Table 1 indicates the detailed costs. As shown in Fig. 1, the i-STAT is more cost effective for monthly testing volumes of less than approximately 800 samples when the total ABL analysis time is 10 min and 1,000 samples when the analysis time is 15 min. The number of anesthesiologists available for sample testing varies, so the usual time required for blood analysis is between 10 and 15 min. From our estimation, the new system would be more cost effective than conventional testing systems using desktop analyzers in most institutions. In fact, the annual number of i-STAT cartridges used in 2008 was 9,375 and the monthly number was 780. It is evident that blood analysis using i-STATs is more economical than that by a conventional desktop analyzer. As is well known, POC testing can reduce testing time; laboratory testing performed using i-STATs can be completed within 2 min. Therefore, this simulation demonstrated that the use of i-STATs can reduce costs and anesthesiologist labor.

The problem with i-STAT cartridges is how to store them. Cartridges need to be stored in a refrigerator, but they must be kept at room temperature for a couple of hours before use to prevent dew formation. In our institution, whole boxes of cartridges are stocked in one large refrigerator and an aliquot of these are kept in each room, because one box of cartridges, which needs to be used within a month, is usually consumed in a week. In conclusion, our new system will improve perioperative management of patients, reducing costs, time, and labor. A downloader with the features described above will soon be released and we hope that it will be adopted as soon as possible.

**Conflict of interest statement** Fuso Pharmaceutical Industries Ltd. has not provided the author with any type of compensation.

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