Bedside Vital Signs Capture for the non-ICU Setting – An Open Source, PC-Based Solution

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Abstract:

The efficient and reliable capture of vital signs and other bedside data in the non-ICU setting has been a challenging problem for the medical informatics community. The problem is compounded by the complexities associated with storage of this data into an electronic medical record system (EMRS). There are a lack of off-the-shelf solutions that satisfy the basic system requirements of bedside data capture, user authentication, data validation prior to storage, error handling, and convenience. With the current state of technology available, we feel the solution to this problem requires the presence of a PC with custom interface software at the bedside. This allows for the successful interface between available vital signs capture devices, existing EMRS's, and the user. This report summarizes the alternatives we found and our proposed solution to this important problem.

Background:

Nurses on non-ICU hospital wards routinely gather large amounts of quantitative data. Blood pressures (BP), pulses, temperatures, intakes, outputs, oxygen saturation, finger stick glucoses, body weights, and other measures. For each set of data they also must record the patient's identity (name or medical record number), the date and time, and the identity of the person recording the measurement (in manual systems usually via a signature). In traditional paper systems these numbers are usually recorded many times, on a work sheet, in the nursing notes and on the bedside temperature chart. These recording and re-recording efforts are error prone and time consuming. Indeed, some feel nurses spend up to 50% of their time performing documentation tasks.[1]

For years, experts have argued that data measured at the bedside should be entered into the computer at the bedside. This reduces cost, avoids intermediate transcription from intermediate work documents to the computer, and reduces the delay in computer availability of this data.[2,3] One group showed that bedside data entry also eliminated the need to wait for an available entry terminal as occurred at the central nursing station.[4,5,6] This same group also showed that nurses markedly preferred bedside data entry over nursing station entry.

Many bedside measurements, including many of the most frequently obtained hospital measurements (BP, pulse rate, and temperature) can be measured by automated machines, and in principle, this subset of bed side observations could be transmitted to the computer directly with out any manual entry.

Since 1989 we have had an almost perfect solution to the bedside data-capture problem. (See Figure 1). The solution came from a commercial vendor, Critikon, that provided automated entry of the blood pressure, pulse and temperature measurements. It also provided for bedside capture of other measures by keypad. The bedside device includes an automated BP machine (based on oscillometry), a temperature probe, ten keys in a linear layout and 2.5 X 9 inch LCD screen. The meaning of the keys is programmable and labeled by words on the LCD above the keys. These keys can also be used for data entry. The bedside unit displays the automated measurements when they are captured but requires the operator to confirm before they are transmitted for storage to a dedicated ward computer. The ward computer provides a number of printed reports, including a graphical temperature chart that can be placed on the bedside clipboard. The ward computer

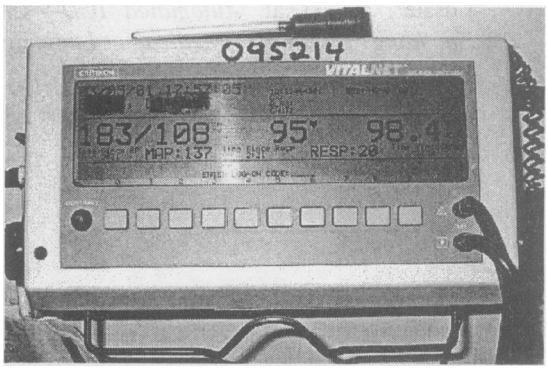

Figure 1 – VitalNet Bedside Unit

also forwards all measurements to our central EMRS as it receives them.

Over the years the VitalNet system has proved savings in nursing time by eliminating duplicate charting. It was always hard to find bedside collected data with the traditional methods, because the recording on the bedside clipboard often lagged the actual collection by hours. We have tried a number of other mechanisms for capturing vital signs via nurse entry onto the computer, but none of them succeeded.

Everyone has benefited from the VitalNet approach. It saves nurses' time and eliminates uninteresting clerical work. To physicians it provides instant availability of the bedside information and vital signs trend data to the flow sheets they can review on order entry workstations and/or pocket rounds reports[7]. VitalNet eliminates the time wasted on rounds looking for the latest results. To the administration it provided a low cost solution that improved efficiency and nursing morale. (The system cost was less then $2000 per bed when it was installed.)

Data Collection Volume:

Our EMRS keeps track of each transaction (when a user performs a save at the bedside terminal). The typical vital signs transaction contains a diastolic BP, Mean BP, systolic BP, temperature, date and time of the recording, location of the recording, patient identification number and user identification information – all distinct variables. A total of 140 beds are equipped with VitalNet bedside devices. In the year 2000, these devices sent 264,295 transactions to our central EMRS. This translated to 22 thousand transactions per month, 722 per day, and nearly 5 transactions per bed per day. Assuming the minimum of eight variables per transaction, this system collected nearly 2 million data elements (264,294 X 8) without any manual entry except the entry of a username and password. If it took only one minute per transaction to find the chart and record this data for each of these transactions, it would require more than two person-years to record these 264,295 transactions onto a paper chart. We believe that the one-minute per patient for recording the transactions is conservative. Thus the automation of these tasks has considerable value.

Our Need for a New System:

The company that originally sold us the VitalNet system was bought out by Johnson & Johnson. For business reasons, they discontinued the VitalNet product, but did continue to produce and market the Critikon Dinamap blood pressure machines as portable, stand-alone devices. (The same mechanism was at the core of the VitalNet Wall mounted bedside devices.) For this reason we were never able to expand the system to all hospital beds. Johnson & Johnson provided us with the source code for their VitalNet data collection software in 1995 and we have supported it ever since -- using about 5% of one programmer's time. Many of the hardware components of the bedside devices are available from Johnson & Johnson because they come from the Dinamap or from general commercial sources (e.g. the temperature probe covers), but some of the parts, e.g. the LCD screens on the bedside units are not available from any source. Since the LCD screens are now beginning to fail, we need to consider replacement systems for our bedside vital signs and data capture system.

Features of the VitalNet bedside data capture system we want to replicate:

Based on Nursing regulations and opinions of the nursing leadership, five features of the VitalNet system were considered essential requirements of any replacement:

1. Permanent devices in each room

Having the devices bolted to the wall was considered a major benefit by nursing in every discussion group. The rolling blood pressure machines (whether automated or manual) are never where you want them. Nurses and physicians waste considerable time scurrying around to find a blood pressure machine to do their routine work.

2. User Authentication:

State regulations in Indiana and many other states require that the person who records a measurement be identified. In a manual system this means that the person must sign the chart next to their observations. In the automated system this translates recording of user identity along with the patient data they commit to storage.

3. A chance to verify the results:

The VitalNet bedside unit displays the results that it produces and gives the user a chance to see them before they are transmitted to the EMRS for storage. This is important, because the results may be off for one reason or another, and users can repeat a measure if they don't like the first one.

4. Bedside availability of the last results:

The VitalNet displayed the last set of results that were entered in large (1/2 inch) fonts that were visible from the foot of the bed so the latest results are immediately visible to clinicians as they round.

5. Ability to enter other data at the bedside:

We used the VitalNet devices to enter other bedside measurements such as intakes and outputs, finger stick glucoses, occult blood tests and weights and oximetry measurements.

Weaknesses of the VitalNet system that we would like to correct in a replacement:

1. Password management

The VitalNet system defined a password access with a maximum of 4 digits. This was not compatible with our system wide user ID and passwords, and it required an extra effort to assign passwords. Further, because of the limited set of passwords we could not assign them to medical students who rotate through the hospital each year. We would like a system that would use our general ID and password approach.

2. Non automated input:

The VitalNet bedside unit had only ten keys for all data entry. So entering clinical data was not as easy. Further, the bedside unit did not perform range checks on numeric values. We would prefer a full keyboard for greater ease in data entry, and better and more thorough error checking.

3. Assignment of patients to beds:

A separate step was required to link patients to bed numbers so that the VitalNet system would know what patient was assigned to what bed. We would like to link to our central EMRS so that this information would not have to be reentered.

4. Patient Name at top of screen:

The VitalNet bedside unit displays the patient name at the top of the screen in small characters. We would prefer the patient name to be displayed in a larger font so the user could more easily verify the patient identity.

Replacement Options:

Intensive care monitoring systems have most of the direct data capture mechanisms we are interested in. They include modules for measuring blood pressures and pulse by oscillometry, temperature probes and oximetry interfaces. However these tend to be very expensive and/or require major workflow changes to accomplish our specified goals. For example, the monitors rarely provide a way for a user to authenticate themselves and to pick and verify a particular value for storage. The data tend to flow as a continuous stream to a central system.

As it turns out there are at least three companies that manufacture devices that are close in function to the VitalNet bedside units. They automatically capture the data of interest to us (BP, pulse, temperature and pulse oximetry) and provide a simple interface mechanism for controlling their device, e.g. the controlling system can command it to take vital sign measurements and return that data to the controlling system through its interface.

A summary of these devices and their features is given in table 1. The prices listed are best estimates, but one might expect better pricing depending upon the number ordered. We have built interface software for, and tested both the Dinamap and Nasiff devices. Both were easy to implement and we believe we could implement an interface to any similar devices with 1-2 day's work.

Critikon's Pro 400 and Datascope's Accutorr Plus are very similar in features and functionality. They both have built in displays and have RS-232 interfaces for controlling the devices. They also can be run in stand-alone mode through their front panel if the PC is down.

Nasiff Associates' CARDIO Diagnostic System consists of a small peripheral black box that connects to a PC via a PCMCIA card. The power for their unit is derived from the PCMCIA interface itself. Nasiff will also have a USB interface by the end of 2001. Their device is capable of acquiring BP, pulse, temperature, pulse oximetry and even 12-lead EKG's. However, the pulse acquisition is derived from their EKG tracing module. They plan to implement a pulse derived from the oscillometry blood pressure in the future. It would be impractical to hook up the EKG leads to acquire the pulse.

The Replacement Solution

The solution is a stand-alone vital signs capture device coupled with a PC program that communicates with the device and our existing

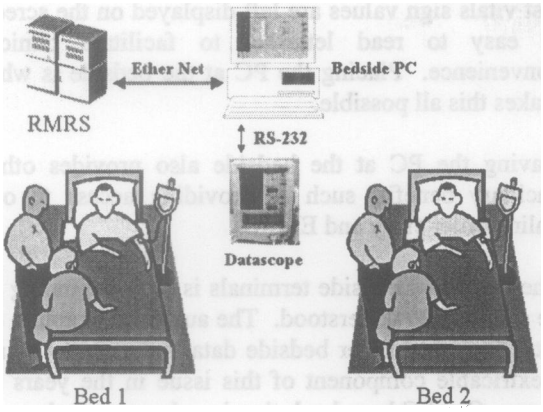

Figure 2 – New System Architecture

central EMRS and also accepts direct input from the user. (See Figure 2.)

Our solution requires the placement of one vital signs capture device and one PC with an LCD monitor in each room. We have developed a C++ program called the Beside Capture Control Program (BCCP), for controlling the bedside device, communicating with the EMRS and collecting input from the user. This program allows the user log on, identify the patient of interest, and ask for measurements (BP, pulse, temperature, and/or oximetry) to be taken. It also lets the user enter other bedside data and confirms the user Identification by querying the central EMRS (which in our case is the Medical Gopher System[8]). The patient selecting menu shows the two patients in the room or current bed assignments. When the patient is selected, the name and patient number are shown in a large font, with a large red arrow pointing toward the bed where the patient lives. (See Figure 3). The values are shown on a panel on the right when the patient is to the right of the PC and on the left when the patient lives to the left of the PC. This feedback about which patient and where they are located is important to avoid entering the right data on the wrong patient.

The BCCP also delivers the confirmed results (labeled with username, patient ID and time stamp) to the central EMRS via an HL7 message. Finally it provides an ongoing display of the last vital signs taken from the patient in the right bed and the left bed (as shown in figure 3.)

It is a fairly simple and generic program that can be interfaced with a central EMRS that can deliver the patient list and confirm the user ID and password. The same exact strategy would also work in an outpatient clinic or emergency room setting where vital signs are captured at a nursing station where the patient comes for measurements before they are placed in a room. In this case the nurse would have to enter in the patients' ID numbers manually by keyboard.

This is a more unified approach than we had with the VitalNet system. We will no longer have to register the patient bed location into the bedside data capture system. We don't have to manage two different user ID's and passwords because the BCCP confirms the user ID and password with the EMRS. It simply forwards the clinical results it captures as HL7 messages. Furthermore, a full alphanumeric keyboard is available for more extensive manual data collection that might be needed.

This same approach could be used in many institutions with different central EMRS by tailoring the patient bed location and user access control links to the EMRS according to its requirements. We will provide the source code to interested users to make that possible.

There are a few special hardware requirements. The screen has to be a flat LCD type because of space limitations. LCD screens are not susceptible to burn in like CRT screens so we can leave the last patient's values on the screen without risk to the hardware. In addition it requires a small sized computer.

The cost per bed will be approximately $2900 per bed, assuming two beds per room (not counting installation) -- $4200 for the automated device, $1300 for a small computer (e.g. Toshiba Equium 8100S with a ViewSonic VP140 14 inch flat panel LCD display.)

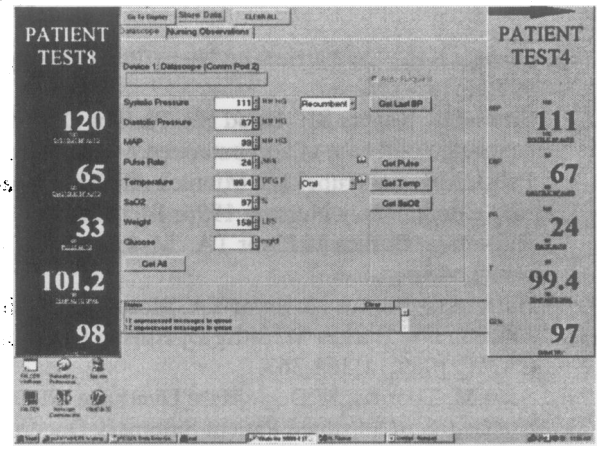

Figure 3 – Bedside Capture Control Program Display Screen

Summary:

The presence of the PC between the bedside devices and the EMRS provides for open and easy integration with several different vital signs acquisition devices. This provides the flexibility that is essential in order to incorporate the system requirements as outlined previously. We get direct data capture of vital signs (BP, pulse, temperature, and SpO_2) as well as bedside data entry of other associated clinical data (respiration rates, finger stick blood glucose, and weights, I/O's). Security is maintained with username/password protection along with an audit trail for all data stored in the EMRS. Error handling is accomplished through our existing EMRS. The last vitals sign values are left displayed on the screen in easy to read lettering to facilitate clinical convenience. Placing the PC at the bedside is what makes this all possible.

Having the PC at the bedside also provides other ancillary benefits such as providing access to our online order entry and EMRS.

The impact of bedside terminals is only beginning to be studied and understood. The automated capture of vital signs and other bedside data is certain to be an inextricable component of this issue in the years to come. Our PC-based solution is only one of what are probably going to be many offered in the future.

Model	Manufacture	Interface	Functions	Price
Accutorr Plus	Datascope Corp. Patient Monitoring Division 800 MacArthur Blvd. Mahwah, NJ 07430 www.datascope.com	RS-232	BP, Pulse, Temp, SpO2	$4200
Dinamap Pro 400	Critikon, a Division of Johnson & Johnson Medical, Inc. 4110 George Road Tampa, FL 33634 www.dinamap.com	RS-232	BP, Pulse, Temp, SpO2	$4800
CARDIO-Card	Nasiff Associates Inc. P. O. Box 88 Brewerton, NY 13029 www.nasiff.com	PCMCIA *USB expected by end of 2001	BP, Pulse, Temp, SpO2 (also has option for 12-lead EKG)	$3700

Table 1 – Bedside Vital Sign Capture Devices

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