International Journal of Clinical Monitoring and Computing 5: 45–51, 1988

Portable computers used for respiratory care charting

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Accepted 15 January 1987

Key words: portable lap computer, respiratory care, charting

Abstract

We studied the feasibility of using a portable lap computer (PLC) for bedside documentation of respiratory care procedures. Three Radio Shack TRS-80 Model 100 (PLCs) were used to capture and transfer the charting by phone into the hospital information system (HIS). Charting on the PLC could be done anywhere at the convenience of the therapist. Transferring data from the PLC to the HIS could be accomplished from any patient room, since all had phone jacks. Once information was entered into the HIS, it became immediately available for review on all nursing station terminals. A 39-day study of 5,019 entries was conducted using 12 therapists of whom 6 were randomly selected to carry PLCs and the other 6 used conventional ward terminals. We found that: 1) There was no statistically significant difference between PLC and nursing terminal entry in productivity or promptness of reporting; 2) Ward terminals were generally available for entry; 3) Cost, maintenance, initial training required, and therapist preference favored ward entry. We conclude that a PLC can be used in a clinical setting as a means of collecting and reporting data from the bedside, and as an input device to a larger computer system, but offers considerable disadvantages in comparison to entry at conventional terminals on the HIS if they are readily accessible.

Introduction

Recently, there have been many applications of the hand-held computer in pulmonary medicine [1–9]. Since the duties of a respiratory therapist often involve simple calculations of respiratory values, calculators are commonly used in routine practice. Programming hand-held computers can provide not only results, but clinical interpretations [1–7]. Although these applications are very useful, there have been few applications of an hand-held computer to routinely chart patient data [10, 11].

Rationale

Since most respiratory care information is not acquired from electronic interfaces or instruments, it must be manually recorded. Therapists do not have a permanent work station since work is performed primarily at the bedside. Entering computer information therefore requires having access to a terminal in many locations, or having a method of recording information on a sheet of paper that could later be entered in the Respiratory Care Department [12].

The concept of using a portable lap computer (PLC) for charting is to directly collect respiratory

* Study conducted at the LDS Hospital.

care documentation at the bedside into an electronic format, and then transfer the data to the Hospital Information System (HIS), permitting rapid and more efficient bedside charting without requiring numerous terminals. The Respiratory Care Department could maintain its own computer resources without interfering with the use of existing HIS terminals at the nursing stations. We undertook our study to determine whether use of PLCs for data entry might better utilize the resources of the main computer system and help make the entry of data a 'paperless' process.

Development

Within the last few years many small portable computers have been developed and marketed [13]. At the time of this project's inauguration, only a few of these computers had sufficient capabilities to be used easily as a remote device and be interfaced to a larger system. The ideal PLC would be small in size, programmable, battery powered, and would have a sufficient amount of memory to provide a 'user friendly' program and to store multiple charting results. It would also have an acceptable interface that could allow transfer to the HIS, and have a large enough display to permit an easy review of charting and provide entry selection.

The Radio Shack TRS-80 Model 100 [14–17] (Tandy Corp, Ft. Worth, TX) (Fig. 1) was commercially introduced when we started this project. It was selected as a suitable computer because it had 32 K bytes of memory, an adequate display (8 rows × 40 columns), and a built-in, 300 baud-rate modem. The modem permitted transmission of data from any telephone, including the phone jacks in each patient's room.

A program for PLC entry was developed similar to the program for respiratory care data entry on the HIS [12]. The PLC program was written in Microsoft BASIC [17] and provided a means of displaying and obtaining acceptable answers from over 90 different question screens. The PLC user answered the question displayed on the screen by choosing among either multiple-choice, entering numeric values, or 'free text' entry. Selections for multiple choice questions ranged from 1 to 24, and selections for each numeric entry question ranged from 1 to 15. All respiratory care charting on the HIS could be accomplished with the PLC program.

The program provided for data review (Fig. 2A), and results could be edited similar to the HIS entry program. Answers to questions were used to build an 'answer string' (Fig. 2B) that could run the HIS entry program via the built-in modem when data were transferred from the PLC to the HIS.

One of the tradeoffs of developing the PLC program was deciding how much memory was required for the program text itself and how much was available for storing results. With the wide variety of entries needed for charting the programming required left little memory space for storing results. The memory required for the PLC entry program was approximately 23 K Bytes (75% of the 32 K Bytes available on the PLC), which allowed about 40 different procedures to be charted. An answer code for a procedure's result took less than 200 Bytes, whereas, a text entry required about 800 Bytes (compare Fig. 2B to 2A). If the text entry method had been used only 6 to 15 results could be stored before the memory was full, necessitating data transfer.

One of the built-in programs of the TRS-80 Model 100 is a telecommunications program that allows for automatic dialing and entry to remote computers. This communications feature provided an easy means of calling a telephone number, entering a password, and transmitting results to the HIS. The PLC entry program used the telecommunications program for entering the 'answer string' to the respiratory care charting program on the HIS. The therapist transferred charting data by attaching to a modular phone jack in the patient's room. Using an option on the entry program, the patient's charting data could be transferred by simply pressing a key on the keyboard. The program would automatically call the HIS computer, log onto the computer by using a password, enter all the charting results using the 'answer string', and disconnect from the HIS computer. To ensure a correct transfer of respiratory care charting, the HIS computer checked patient identification and proper sequence of charting, which permitted verification of the accuracy of the transmitted data.

Fig. 1. Photograph of portable lap computer (PLC) used for charting respiratory care procedures.

When multiple entries were transferred, the PLC made repeated calls, transferring one result at a time until all chart data stored in the PLC memory were transferred. It was assumed that most transfer of data would be done immediately after charting a procedure. The Model 100's built-in auto dial program handled a single transfer easily. The PLC program flagged transferred charting so that it would not be retransmitted and as a consequence be charted twice.

The PLC could also be used as a stand-alone device and generate its own reports. A problem with PLC generated reporting was that all text entries had to be saved in memory on the PLC. It is apparent from Figure 2 that saving only the coded answers required much less space than saving both the answers and the text. The generation of reports also required the availability of a suitable printer. Therefore, a PLC generated reporting was not used in this study.

Methods

The PLCs were evaluated in four areas:

1. Therapists' appraisal,
2. Observations of work patterns,
3. Timing studies, and
4. Cost and maintenance estimates for PLC entry.

Three TRS-80 Model 100s were available for use. Entry using PLCs was evaluated using randomly selected therapists during the same time period and at the initiation of computerized respiratory care charting. For our study we selected six dayshift and six evening-shift therapists from the group of full-time therapists who worked primarily on routine procedures (i.e., non-ICU and non-newborn nursery personnel). From this group of 12 therapists, three day-shift and three evening-shift therapists were randomly selected (their names were drawn from a hat), and each was assigned to use a PLC. The other six therapists used conventional terminals along with the rest of the department.

A survey of therapists using the PLCs was carried out using a questionnaire. Changes in work patterns were also observed by questioning the

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*** 10/28/85.14:38
PT# 1111111                THPST# 33333;
   THERAPY:MED NEBULIZER,CPT: PATIENT IN
TERFACE:MOUTHPIECE;  POSITION:SITTING;
PRE:HEART RATE (/MIN) ___ 80,RESPIRATORY
 RATE (/MIN) __ 20;
          (enter to continue)


*   PRE BREATH SOUNDS:WHEEZING:  BLL: PR
E BREATH SOUNDS:RHONCHI;  RML;  MEDICATI
ONS:ALUPENT;  10 MG;  NORMAL SALINE;  TY
PE OF PERCUSSION:MECHANICAL;  TIME OF PE
RCUSSION (MIN) __10;
          (enter to continue)


*  BLL;  COUGH:FREQUENT;  MOD,PROD;  SPU
TUM;SPONTANEOUS;  QUANTITY (CC) __5;  CL
OUDY;  THICK:  POST:HEART RATE (/MIN) __
_ 88,RESPIRATORY RATE (/MIN) __ 22;  POS
T BREATH SOUNDS:UNCHANGED;
          (enter to continue)


*  PATIENT CONDITION:ALERT;  PATIENT ATT
ITUDE:COOPERATIVE;  COMMENTS:PT IS SICK;
  THERAPIST DURATION __20;
          (enter to continue)
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A

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1111111^M?-=10/28/85.14:38;2,4;;1;1;80,2
0;4;;6;5;;9;;;,;2;2;2;;1;10;;6;1;2;1;5;2
;1;^M?_==88,22;10;;;;;;1;1;;PT IS SICK;,
20,5;33333;
          (enter to continue)
```

B

Fig. 2. A Review of charting results on the portable lap computer (PLC); B. Answer codes sent to the Hospital Information System.

therapists as well as the nurses and ward clerks at the nursing stations. Timing studies were conducted to answer three questions: 1) Were therapists more productive using the PLCs? 2) Did the PLCs make data reporting more timely? 3) Was it faster to enter data into the computer using PLCs than using nursing station terminals? All data for these studies were collected from the therapists' 24-hour management report [12]. The 24-hour management report was useful for verifying completion of procedures. The report included: when procedures were entered, how promptly the results were reported, and how much time was used on the HIS computer system for data entry. Timing information was automatically captured on both the HIS and the PLC when entering and verifying results. An unpaired t-test was used for comparison testing between PLC and conventional ward-terminal entries.

The final area of evaluation for PLC entry involved estimating the cost of implementing PLC entry for the entire department, and other expenses such as maintenance (both hardware and software). Other topics of consideration were theft, damage, and security of patients' information.

Results

The most significant result of the six questionnaires from the therapists using PLCs was that *all* six therapists preferred ward terminal entry for charting (Table 1). Their most preferred way of using the PLCs was to chart on the PLC in the patient's room and transfer results from either the nursing station or the Respiratory Care Department. Therapists took longer to feel comfortable charting with the PLCs than with ward terminals (approximately 9 days versus 3 days, respectively). The most common complaint from those using the PLCs related to transferring results to the HIS (either it was too

Table 1. Ranking of charting method by the six PLC-assigned study therapists (1 = most preferred, 4 = least preferred).

Charting method	Therapist					
	A	B	C	D	E	F
Portable computer entry	3	3		4		4
Ward terminal entry	1	1	1	1	1	1
Dept terminal entry	2	4		2		2
Manual	4	2		3		3

slow, or inconvenient (even though there were phone jacks in every room) or problems in transfer occurred.

One of the advantages of using a PLC rather than a note pad at the bedside was that the therapist did not have to return to the nursing station and duplicate the charting. While PLCs were used to capture charting data at the bedside, PLCs did not eliminate the making of manual charting notes. Charting notes were still made on work sheets for use in giving report to other therapists at shift changes and to mark off completed procedures for the supervisors to review. Thus, charting with PLCs did not reduce data entry to a 'paperless' process.

Although it was suggested that therapists chart a procedure and transfer results immediately in the patient's room, the option was left with the therapists to perform their jobs as they felt best. The therapist questionnaire showed that work patterns varied among the six therapists. One therapist preferred to transfer results in the room for a previous procedure while providing therapy on the current patient. Another therapist preferred not charting in the patient's room because it was thought 'more important to have personal contact with the patient rather than share time with the computer.' Another preferred transferring at the nursing station while looking up reports on patients at the ward terminal. Others thought it more convenient to transfer a 'batch' of charting at one time.

The therapists who charted at ward terminals generally had little trouble getting access to a terminal. For the most part, nurses and ward clerks reported that computer charting by respiratory care personnel did not prevent others from having access to the terminals, although on the busier wards there were times when there were delays in getting terminal access.

Results of timing measurements are presented in Table 2. Entries from the PLCs accounted for 11.4% (1,592 entries) of all 13,965 total entries in the Respiratory Care Department computer charting during the 39 day study period. A total of 5,019 entries (36% of Respiratory Care Department entries) were made by the two groups of therapists in our study. The six therapists assigned to ward terminals made 2,830 entries. The six therapists assigned to PLCs made 2,189 entries. Of these 2,189 entries only 1,592 (73%) of those entries were made using the PLCs despite the fact that they were strongly instructed to use PLCs exclusively. For both productivity (time allocated for the proce-

Table 2. Timing study comparing data entry at Ward terminals to entry via portable computers.

Therapist	Productivity	Turnaround time (sec)	HIS computer time (sec)
	Ward terminal entry		
A	1.56	34.7	1.69
B	1.37	33.6	1.88
C	1.73	37.5	2.42
D	1.57	56.1	1.95
E	1.44	188.2	1.56
F	1.42	51.8	1.34
Average	1.52	67.0	1.81
	PLC entry		
G	1.64	78.5	0.89
H	1.78	68.4	0.72
I	1.33	109.0	0.79
J	1.40	20.0	0.79
K	1.72	94.6	0.91
L	1.51	133.3	0.84
Average	1.56	84.0	0.82
p value (unpaired t-test)	NS	NS	<0.0001

dure/duration of procedure) and *turnaround* time (time procedure reported on HIS – time procedure was started – duration of procedure) there was no significant difference between those using PLCs and those using ward terminals for entry. Computer time (HIS Computer Time in Table 2) used to transfer the data from the PLC was significantly less ($P<0.00001$) than using ward terminal entry. This time does not take into consideration the time previously spent charting on the PLC. If the total charting time were included, then total time entering results with the PLC was greater than the time taken to chart on ward terminals. Transfer time (average of 877 sample entries) of entering one procedure into the HIS computer was 78.6 seconds, of which 30 seconds were spent in the automatic phone call procedure, entering a password, requesting the entry program, and disconnecting from the phone.

Computer charting time for the Respiratory Care Department averaged nearly 11 hours (351 entries) per day during the study period. The average reporting turnaround time for the department as well as for the 12 study therapists was 75 minutes and the average HIS computer time per entry was 1.68 minutes.

A cost breakdown presented in Table 3 estimates the expense of implementing the Respiratory Care Department with PLCs for data entry. New batteries were required about every 3 days. During the study period, no PLCs were lost or stolen, although two PLCs were slightly damaged (a key lost and a broken space bar key). The PLCs were still operable after these accidents. To implement PLC charting, the Respiratory Care Department would require a minimum of 10 PLCs for use on nursing divisions; therefore, an initial expense of over $13,000 was required, as well as periodic maintenance costs.

Table 3. Approximate costs for using portable computers for data entry.

Initial Cost	
TRS-80 model 100 portable computer	$ 1,000 each
Modem cables & connectors	$ 25 each
Protective carrying case	$ 75 each
Sub total each	$ 1,100
(2) Modems for HIS entry	$ 1,000
(1) Ports on tandem computer	$ 1,000
(1) Printer	$ 500
Miscellaneous (cables, adapters etc)	$ 200
Subtotal	$ 2,700
Cost for 10 units	$13,700
Maintenance cost	
Batteries	$10/computer/week
Breakage, theft, replacement	(unknown)

Discussion

The portable computers performed reliably. Charting could be done at the bedside, the data could be transferred to the HIS, and entering results did not interfere with access to nursing division terminals. Over 1,500 PLC entries were made during the study period. There were no instances of incorrect data transfer. Although using portable computers for charting was shown to be a feasible method for entering data, therapists using the portable computers preferred using ward terminals for entry. Although PLCs did eliminate entry at nursing division terminals, therapists still used ward terminals to review previous patient reports. Carrying a PLC was sometimes difficult when therapists were also transporting respiratory care equipment. The 1.8 kg computer had to be carried the entire shift, although it was used for less than an hour during the shift.

A consideration in adopting the use of PLCs were hardware and software costs. Similar with trends in computer hardware, the portable computers used in this study are now much less expensive and other models have been introduced. It is difficult to give an estimate of the cost of software maintenance. Any change to the entry program of the HIS requires a similar change on the PLC entry program. Software maintenance and development costs had to be duplicated and two systems supported.

LDS Hospital plans to have a terminal at each patient's bedside within the next 5 years. Thus purchase and use of PLCs would only have been a temporary measure until these terminals were in

place. The clinical acceptance of using PLCs for data entry was in many ways hinged on the accessability and acceptability of using nursing division terminals. If the entering of charting interfered with the review of information used for patient care by nurses or physicians, then the computer would actually hinder the main purpose of documentation [17]. If access for entry on the wards was difficult, then three options remained: 1) return to the manual system; 2) perform data entry in the department; or 3) use PLCs. If there had been problems with obtaining access, using the PLCs would likely have been the option chosen. Manual charting has been shown to be inferior in most aspects to computer charting [12]. Respiratory Care Department entry would have required two full-time clerks for computer data entry (total computer entry time was about 11 hours per day) or would have required a large number of terminals in the Respiratory Care Department for therapists to enter their own charting. Even if therapists could have easy access to terminals in the Department, the turnaround time of reporting would have been prohibitively long and would also have required the therapists to make more frequent trips between the nursing divisions and the Respiratory Care Department, decreasing their efficiency.

The therapists' survey showed that there was little trouble getting access to a terminal on the wards, although there were times during the day when access was difficult. Busy access times were encountered during the day shift, especially in the mornings and at shift change. By making use of the less busy times for entry, the Respiratory Care Department optimized its data entry and minimized competition for terminal use.

In this study, PLC entry was compared to entry at nursing station terminals. This study was also performed in a hospital with a highly developed HIS; a more general study might investigate the feasibility of using PLCs to transfer to a smaller computer system or personal computer in the Respiratory Care Department. Such an alternative would requires the generation of cumulative patient charting and billing reports, but might still prove very beneficial and cost effective.

While the portable computer was not found to be an optimal means of entering patient information, use of ward terminals has to a large degree replaced the patient's conventional chart. This study has shown that a portable computer can be used in a clinical setting as a means of collecting and reporting data from the bedside, and as an input device to a larger computer system, but offers considerable disadvantages in comparison to entry at conventional terminals on our HIS if these terminals are not busy.

References

1. Silage DA, Maxwell C: A spirometry/interpretation program for hand-held computers. Respir Care 28: 62–66, 1983.
2. Gardner RM. Information management-hemodynamic monitoring. Seminars in Anesthesia 28: 452–456, 1983.
3. Silage DA, Maxwell C: A lung volume determination/interpretation program for hand-held computers. Respir Care 28: 452–456, 1983.
4. Hess D: The hand-held computer as a teaching tool for acid-base interpretation. Respir Care 29: 375–379, 1984.
5. Silage DA, Maxwell C: An acid-base map/arterial blood-gas interpretation program for hand-held computers. Respir Care 29: 833–838, 1984.
6. Hess D, Silage DA, Maxwell C: An arterial blood gas interpretation program for hand-held computers. Respir Care 29: 756–759, 1984.
7. Silage DA, Maxwell C: A lung diffusion determination/interpretation program for hand-held computers. Respir Care 28: 1587–1590, 1983.
8. Enright PL: A hand held computer simplifies lung testing. Proceedings of the Sixth Annual Symposium on Computer in Medical Care (SCAMC) 649 IEEE Computer Society, 1982.
9. Maxwell C, Silage DA: Hand-held computers in pulmonary medicine (editorial). Respir Care 28: 35–36, 1983.
10. Mertz SL, Ash SR, Farrell J: The CNS in the ICU: A bedside notation system for nurses. Proceedings of the Sixth Annual Symposium on Computer in Medical Care (SCAMC) 577–581 IEEE Computer Society, 1982.
11. Ash SR, Ulrich DK: Direct entry of patient data to a portable briefcase computer: interface with overview medical data base at the office. Proceedings of the Seventh Annual Symposium on Computer in Medical Care (SCAMC) 350–352 IEEE Computer Society, 1983.
12. Andrews RD, Gardner RM, Metcalf SM, Simmons D: Computer charting: An evaluation of a respiratory care computer system. Respir Care 30: 695–707, 1985.
13. Lu C: Dawn of the portable computer. High Technology (9): 35–51, 1983.

14. Kelly MG: The Radio Shack TRS-80 Model 100. BYTE (9): 139–162, 1983.
15. Stewart G: The TRS-80 Model 100. Popular Computing (5): 86–165, 1983.
16. TRS-80 Model 100 Portable Computer Owners Manual. Fort Worth, TX: Tandy Corp, 1983,
17. Warner HR: Computer-assisted medical decision-making. Academic Press, New York, 1979.