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# COMPUTER ASSISTANCE IN DELIVERY OF PATIENT CARE IN A NEONATAL INTENSIVE CARE UNIT

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## INTRODUCTION

We are living in the midst of a revolution in information processing. Startling increases in speed and storage capacity of computers, as well as consistent downward trend in cost, size, and power consumption, have led to a proliferation of computers far beyond the wildest dreams of anyone in the field 20 years ago. Millions upon millions of microcomputers are being incorporated into every imaginable type of electrical device, from televisions to electronic ignitions. It is expected that within three years, something as complicated as the entire instruction set of an IBM 370 computer can be incorporated into a single integrated circuit.

This astonishing progress in the computer industry, however, has contributed surprisingly little to the day-to-day practice of medicine. It is true that in specialized instances, such as the computerized axial tomography (CAT) scanner and the multichannel automated analyzer, embedded computer systems have given us powerful new diagnostic tools. Nevertheless, the impact of the computer in delivery of direct patient care has been minimal. Many ambitious tasks ranging from patient interviewing to antibiotic selection have been undertaken and published, but a recent follow-up study of reports in the internal medicine literature reported that only 19 percent of announced projects in computer-assisted health care had come into routine use.[1]

The reasons for these failures are diverse. (See also Chapter 1.) Physicians place a high value on their own time, are intolerant of technical jargon when it is not their own, and are impatient with the problems that are naturally encountered in the development of an innovative computer application. Computer scientists, for their part, are frequently isolated from the user environment and have found it "interesting" to write programs that seek to emulate physicians in complex decision-making processes instead of providing them with useful tools at a more fundamental level. Noisy or inconvenient terminals, slow response times, and cumbersome password procedures have also contributed to resistance by medical personnel.

With the advent of large-scale integrated circuits and inexpensive mass memory, a variety of small but powerful computer systems can be purchased virtually off the shelf. It is now feasible for the sophisticated user to create highly customized applications on dedicated machines and to avoid dependence on the hospital central data processing facility or the campus computer science department. Peripheral devices can be tailored to the problem at hand and need not be selected on the basis of compromises between the needs of disparate users.

The neonatal intensive care unit is ideally suited to the introduction of computer assistance. It is a highly data-intensive environment—probably as numbers-oriented as any area in medicine. Vital signs, weights, intake and output, blood gases, and many other laboratory studies must be monitored frequently and reacted to appropriately. Almost every therapeutic intervention, from endotracheal tube to dose and frequency of antibiotic administration, must be properly selected on the basis of the infant's weight and gestational age. Efforts to apply computer assistance to the problem of data handling in the newborn intensive care area are in progress in several centers. Applications in real-time patient monitoring,[2] data management,[3] incubator control,[4] and admission or discharge summary generation[5-8] have been reported.

A dedicated microcomputer system has been in continuous use at the Cedars-Sinai Medical Center (C-SMC) neonatal intensive care unit (NICU) since 1978. The equipment configuration is a Cromemco mainframe based on the Zilog Z-80 microprocessor, 1 megabyte (MB) of removable flexible disk storage, 22 MB of fixed hard disk storage, several standard CRT terminals, a Tektronix graphics terminal, and a 300 line-per-minute printer.

This chapter briefly describes a number of applications that we have made at C-SMC NICU of this microcomputer system in assisting direct patient care.

## CURRENT APPLICATIONS

Initial applications of the computer in the NICU were directed toward making it serve as a fast and convenient calculation aid and

```
NICU Information Module  version 2.2                          09/20/80

C  =  Census (admit, modify, or discharge patient)
D  =  Dubowitz examination
E  =  Enter weight/head circ. for growth charts
I  =  Quick IV calculation
M  =  Medication library
N  =  General nutrition program
O  =  Old TPN result entry
P  =  Display last 7 days of TPN on terminal
S  =  Print all pending TPN summaries
T  =  Total parenteral nutrition protocol
U  =  Umbilical catheter distances
V  =  View reference library menu
X  =  Enter progress note
Y  =  Print progress note
Z  =  Digoxin dose calculation

Select function:  T
```

FIGURE 19.1. Main selection menu of the C-SMC NICU microcomputer system. Use is made of programs comfortable for medical personnel, inasmuch as computer jargon is eliminated and no typing skill is required.

information resource. The intent here was to save physician time and reduce the number of errors made. Figure 19.1 shows the main selection menu first seen by a user of the C-SMC NICU microcomputer system. A number of the programs listed here were provided to assist the physician in such routine tasks as scoring gestational age (Dubowitz examination), determining intravenous (IV) composition and appropriate infusion rate (Quick IV calculation), and dosing critical drugs (Digoxin dose calculation). Several hundred "screens" of reference information (Medication library, Umbilical catheter distances, and View reference library menu) were indexed for rapid retrieval. These included lists of laboratory test normal values and constituents of the various infant formulas, as well as drug dosages, toxicities, and interactions.

## The TNP Program

Our first direct intervention in patient management was the introduction of an interactive computer program for the administration of partial or total parenteral nutrition (TPN).

To operate this program, the user first picks and confirms a patient from the current census list. The next step is do the following: (1) enter all current laboratory results that might aid in later decision making; (2) record today's weight, which is crucial for the calculations;

and (3) enter IV and enteral intakes for the previous 24-hour period. These forms, with appropriate responses, are illustrated in Figures 19.2-19.4. Together with the composition of the previous day's IV bottle, which is on disk storage, these values are used by the computer to calculate and display an exact analysis of the calories, protein, and electrolytes delivered to the baby the previous day (Fig. 19.5).

The initial step in ordering a new TPN solution is to specify the desired intake for the next 24 hours and to apportion that amount be-

```
Enter todays lab results for Doe, baby girl
(just push <ENTER> if no result today)

Na                   =? 135
K                    =? 4.0
Ca                   =?
Phos                 =?
Mg                   =?
BUN                  =? 9
Creat                =? 0.7
Bili                 =? 2.8
GOT                  =?
GPT                  =?
Ammonia              =? 46
Tot. prot.           =?
Albumin              =?
Chol                 =?
Trigly               =?
Hct                  =? 40
Plat (K)             =? 135

Do you wish to correct any results? (Y/N) :  N
```

FIGURE 19.2. Second TPN program CRT terminal frame, requesting today's laboratory results and displaying sample responses.

tween the IV and enteral routes. The pertinent questions and typical responses are shown in Figure 19.6. Thereafter, successive frames deal with the concentration of dextrose and the amount of sodium to be added in the new TPN solution, as illustrated in Figures 19.7 and 19.8, respectively. A series of other frames not illustrated here aid in decisions regarding how much potassium, magnesium, calcium, heparin, vitamins, and trace elements should be added. Note that in each case a suggested concentration or amount is displayed that can be accepted

```
(Yesterdays IV Calculation)

Enter today's weight (grams)      : 1500

Enter head circ. (cm)             : 28.5

Total cc IV fluid delivered       : 150

Total cc Intralipid delivered     : 15

Were there any feedings? (Y/N)    : Y
```

FIGURE 19.3. Third frame of TPN program, displaying patient's present weight and IV intake over the past 24 hours.

```
 1 Breast milk
 2 D5W
 3 Enfamil 20
 4 Enfamil 24
 5 H2O, distilled
 6 Isomil
 7 MCT oil
 8 Neomullsoy
 9 Nutramigen
10 Pedialyte
11 PM 60/40
12 Pregestimil
13 Prosobee
14 Similac 20
15 Similac 24
16 Similac 27
17 Similac LBW
18 SMA 20
19 SMA 24
20 Vivonex

Select formula: 17      Full strength? : Y        cc of intake: 120
```

FIGURE 19.4. Fourth frame of TPN program, giving choice, strength, and amount of enteral formula intake over the past 24 hours.

```
Yesterday's intake:

                               IV       PO      Total    % PO

Sodium meq/kg                  2.0      1.3      3.3      39
Potassium meq/kg               1.2      2.1      3.3      63
Ca gluconate cc/kg             1.2      5.8      7.0      83

Protein gm/kg                  0.8      1.8      2.6      69

Fat gm/kg                      1.3      3.6      4.9      73

Fluids cc/kg/day             113.3     80.0    193.3      41

Calories/kg/day               54.7     64.0    118.7      54

Do you wish to correct weight or yesterday's intake? (Y/N) :  N
```

FIGURE 19.5. Fifth frame of TPN program, showing computer calculation of intake of electrolytes, protein, fat, fluid, and calories over the past 24 hours.

```
Calculations for next IV:

Fluids cc/kg/day desired (total IV + PO) : 160

Will feedings be given? (Y/N) : Y

Amount (cc) per feeding: 15

How many hours between feedings:  3
```

FIGURE 19.6. Sixth frame of TPN program, showing questions and responses revolving around fluid intake for the next 24 hours.

```
Yesterday infant received 10% dextrose.

Note that today's serum glucose is 74.

Providing urine clinitest less than 1+, suggest increase
dextrose concentration by 1% today.

Do you want IV of 11% dextrose? (Y/N) : Y
```

FIGURE 19.7. TPN program frame, aiding in the decision of what dextrose concentration should be used in the next day's IV solution.

```
Yesterday infant received 2.0 meq/kg/day Sodium IV.

Yesterday infant received 1.3 meq/kg/day Sodium by feedings.

Today's serum Na result = 135.

Do you wish to use the usual IV maintenance amount
of 3 meq/kg/day Na? (Y/N) : N

Then enter meq/kg/day Na:  4
```

FIGURE 19.8. TPN program frame aiding in the choice of the amount of sodium (in mEq/kg/day) to be added in the next day's IV solution.

or rejected by the user with a single-letter reply. This is designed to minimize errors in numeric inputs. In addition, available information about previous intake and current laboratory values is gathered together to justify the suggested changes or help the user make a rapid and correct decision.

In the case of protein as amino acid solution (Freamine) to be infused in the coming 24-hour period, the program attempts to "drive" the IV amino acid intake toward the target amount of 2.5 grams per kilogram body weight per day. It does so by asking the user to advance the dose at specified intervals, as long as liver function test results stay within predetermined safe limits (Fig. 19.9). Likewise, for fat or IV lipid (Intralipid), the program is designed to advance the dose at 3-day intervals toward the target amount of 2 grams per kilogram body weight per day (Fig. 19.10). Again, the suggested increases come only if the appropriate laboratory values being monitored (i.e., bilirubin, cholesterol, triglycerides, and platelet count) are being maintained within normal limits.

```
Yesterday infant received 0.80 gm/kg/day Freamine IV.

Yesterday you ordered 1.00 gm/kg/day Freamine IV.

Note that today's ammonia result = 46.

It has been 3 days since last change in Freamine dose.
With ammonia level in this range, recommend increasing
Freamine to 1.5 gm/kg/day today.

Do you wish to give Freamine 1.5 gm/kg/day? (Y/N) : Y
```

FIGURE 19.9. TPN program frame attempting to "drive" user toward target amount of 2.5 grams of amino acid per kilogram body weight per day.

```
Yesterday infant received 1.3 gm/kg/day Intralipid.

Yesterday you ordered 1.5 gm/kg/day Intralipid.

Note that today's bili result = 2.8.

Suggest continue with same Intralipid dose.

Do you wish to give 1.5 gm/kg/day Intralipid? (Y/N) : Y
```

FIGURE 19.10. Program frame, advising safe amount of fat emulsion (Intralipid) to be infused over the next 24 hours.

```
New IV order for Doe, baby girl  TPN day #27  09/20/80

250 cc of D11W plus 6.4 meq NaCl
plus 1.6 meq of KCl plus 1.6 meq of K2PO4
Plus 0.8 meq of MgSO4 plus 2.4 grams Freamine III
plus 60 mcg Zinc plus 30 mcg Copper
plus 50 Units Heparin plus 2 cc of MVI
to run at 5 cc per hour.

(assuming feedings of 15 cc q 3 hours.)
(NPO IV rate would be 10 cc per hour. )

22 cc of Intralipid to run IVPB over 10 hours.

1.0 cc 10% Ca gluconate IVP q 8 hours.

Vitamin B-12 0.035 mg IM today.

Labs to order for tomorrow:
Na, K, Phos, Mg, BUN, glucose.

Do you wish to accept this IV? (Y/N)              : Y
Do you wish to calculate another IV? (Y/N)        : N
Do you wish to print summaries now? (Y/N)         : Y
```

FIGURE 19.11. Final TPN order, as generated by the computer, with additional suggested vitamin injections and laboratory tests to be ordered the following day.

Figure 19.11 displays the final amount of concentration of each component chosen to be included in the next day's TPN solution. The program display also suggests appropriate laboratory tests to be ordered for the following day, according to predetermined individual rotating schedules. Finally, it gives the option to once again make any desired changes before the order is sent to the pharmacy.

Updated nutritional and laboratory flowsheets are printed daily; a typical example is illustrated in Figure 19.12. Growth charts such

CEDARS-SINAI MEDICAL CENTER

DEPARTMENT OF PEDIATRICS

Permanent Chart Copy

DOE, BABY GIRL
01/0123456

| Date (1980) | 07/17 | 07/18 | 07/19 | 07/21 | 07/22 | 07/23 | 07/24 |
|---|---|---|---|---|---|---|---|
| TPN Day # | 8 | 9 | 10 | 12 | 13 | 14 | 15 |
| Weight (gm) | 565 | 575 | 600 | 640 | 670 | 680 | 715 |
| Intake Previous 24 Hrs | | | | | | | |
| Calories/Kg/day | 78 | 88 | 90 | 104 | 101 | 60 | 82 |
| % PO | 28% | 38% | 47% | 59% | 62% | 0% | 29% |
| Fluids cc/Kg/day | 247 | 236 | 198 | 186 | 184 | 181 | 208 |
| % PO | 13% | 21% | 32% | 50% | 50% | 0% | 17% |
| Protein gm/Kg/day | 1.7 | 2.3 | 2.4 | 2.2 | 2.2 | 2.5 | 2.8 |
| % PO | 24% | 26% | 32% | 50% | 50% | 0% | 15% |
| Fat gm/Kg/day | 2.7 | 3.8 | 4.4 | 6.0 | 5.5 | 1.9 | 3.3 |
| % PO | 47% | 50% | 55% | 58% | 64% | 0% | 40% |
| Na meq/Kg/day | 6.2 | 4.5 | 4.3 | 2.0 | 3.3 | 5.1 | 5.1 |
| K meq/Kg/day | 2.2 | 2.4 | 2.2 | 2.2 | 1.7 | 2.0 | 2.4 |
| Ca cc/Kg/day | 2.8 | 3.4 | 3.4 | 4.0 | 3.1 | 2.0 | 3.1 |
| TPN Targets Next 24 Hrs | | | | | | | |
| Freamine gm/Kg | 2.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Intralipid gm/Kg | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Dextrose % | 5.0 | 5.5 | 5.5 | 6.0 | 6.0 | 6.0 | 6.0 |
| Na | 138 | 132 | 132 | 131 | 135 | | 133 |
| K | 4.5 | 5.0 | 4.2 | 5.0 | 4.4 | | 5.1 |
| Ca | | | | 10.4 | | | |
| Phos | | | | | | | |
| Mg | | | | | | | |
| BUN | | | | | | | |
| Creat | 1.1 | | | | | | |
| Glucose | 115 | 90 | 111 | | 121 | | 122 |
| Bili | 1.7 | | | | | | 1.1 |
| GOT | | | | | | | |
| GPT | | | | | | | |
| Ammonia | 36 | | 34 | | | | |
| Tot Prot | | | | | | | |
| Albumin | | | | | | | |
| pH | | | | | | | |
| Chol | | | | | | | |
| Trigly | | | | | | | |
| Hct | 52.0 | | 47.0 | 50.0 | | 48.0 | |
| Plat (K) | | | | | | | |

Form No. 670 (1/80)

FIGURE 19.12. Flow sheet generated from the TPN program, showing a week of data from an imaginary patient, including progress in weight gain, intake of calories, fluid, protein, fat, electrolytes, and dextrose, as well as all pertinent laboratory values obtained during that time period.

as that illustrated in Figure 19.13 are generated by the computer and graphics terminal once a week for inclusion in the patient's medical record. A more complete description of our experience with computer-assisted parenteral nutrition is in preparation.

## Computer-Assisted Progress Notes

A system of programs to assist in the computer preparation and printing of problem-oriented progress notes is currently in experimen-

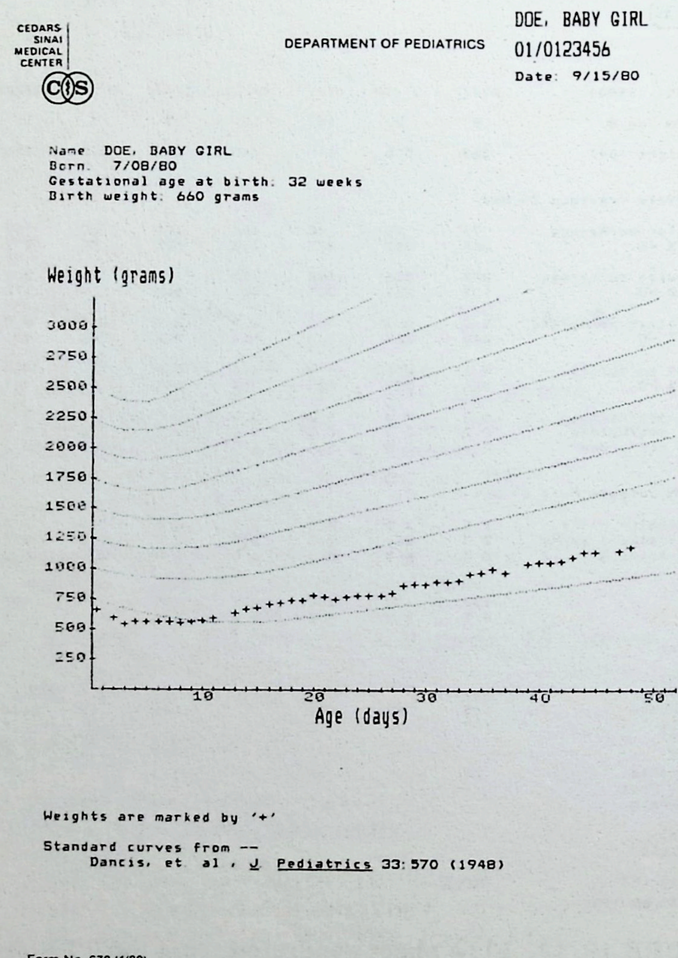


FIGURE 19.13. Growth curve, illustrating weight gain over the first 48 days of an imaginary patient on hyperalimentation, as generated by the graphics terminal on command of the TPN program.

tal use. To write a progress note using this system, a physician designates a patient from the census file, picks one of the patient's problems from a standard list (Fig. 19.14), and then proceeds to answer programmed questions pertinent to the problem selected. Examples of such questions relevant to the problem of hyperbilirubinemia are demonstrated in Figures 19.15-19.17. As can be seen, most questions are molded into a yes-no or multiple choice format, although free-text entry capability is always available. Upon completing one problem,

```
 1    Routine Health Care
 2    Nutrition
 3    Respiratory Status
 4    Metabolic
 5    Infection
 6    Hyperbilirubinemia
 7    Clotting Status
 8    Pneumothorax/Pneumomediastinum
 9    NEC
10    Hypotension
11    Hypertension
12    Cardiac
13    Seizure Disorder
14    Hydrocephalus
15    Intracranial Hemorrhage
16    Congenital Infection
17    Renal
18    Anemia
19    Social

Select problem:   6
```

FIGURE 19.14. Standard problem list for use in computer-assisted writing of NICU progress notes.

others specific to the infant are selected in turn, including findings on physical examination. Upon completion of an infant's problem list, nutritional and laboratory information from the parenteral nutrition files are automatically incorporated, and the progress note is generated on the line printer for the physician's review and signature. Programs are under development to search the patient's cumulative data file and abstract the information into weekly, monthly, or discharge summaries on demand.

```
01/0123456 Doe, baby girl        Problem #6    Hyperbilirubinemia

Working diagnosis?
1   Hyperbilirubinemia of prematurity
2   Hemolytic - ABO incompatibility
3   Hemolytic - Rh incompatibility
4   Secondary to sepsis
5   Secondary to congenital infection
6   Secondary to hepatitis
7   Secondary to GI obstruction
8   Etiology unknown
9   Other
Select 1-9:  1
```

FIGURE 19.15. Sample interaction frame, giving multiple choices for specific diagnosis or cause of the problem hyperbilirubinemia.

```
Phototherapy status?
1   Started today
2   Continuing
3   Stopped today
Select 1-3:  1

Phototherapy type?
1   White lights
2   Blue lights
3   Mixed lights
Select 1-3:  1

Phototherapy intensity [numeric] : 6
```

FIGURE 19.16. Another frame of choices regarding mode of therapy for the problem hyperbilirubinemia, as part of the progress note entry program.

```
Any exchange transfusions in last 24 hours? [Y/N] : N

Do you wish to enter bilirubin result? [Y/N] : Y

Total bilirubin [numeric] : 12.2

Direct bilirubin [numeric] : 1.1
```

FIGURE 19.17. Final frame of questions for the problem hyperbilirubinemia, as part of the computer-assisted progress notes program.

## COMMENTS AND FUTURE DEVELOPMENTS

Medical record departments have resisted many efforts to introduce computerization, but once this is successfully accomplished the rewards will be many. Progress notes will be legible, complete, and organized in a consistent way. Automated summarization will replace the traditionally tardy and incomplete manual methods. Research projects will be benefited when we no longer need to rely on the medical records department to locate the original chart or the investigator's ability to decode it once found.

Future plans for our dedicated NICU microcomputer system include those listed below. (See Fig. 19.18 for schematics of existing and "under development" portions of the NBICU microcomputer system at Cedars-Sinai Medical Center.)

Bedside entry of vital signs, and intake and output data
Shift or daily vital sign graphics
Computer-generated discharge summaries
Linkage to other computer systems within the hospitals, such as those serving the clinical laboratory and the obstetric department

It seems evident to us, with the experience gained thus far, that many of the tasks in the neonatal intensive care area can be facilitated with computer assistance. The current trend toward decentralization of computing resources, placing dedicated systems in the hands of end users, gives us the opportunity to design and implement applications that previously would have been impractical. In return for the continued patience and cooperation of the medical and nursing personnel in our unit, we intend to provide them with an increasingly sophisticated, responsive, and forgiving tool that will simplify rather than complicate their jobs.

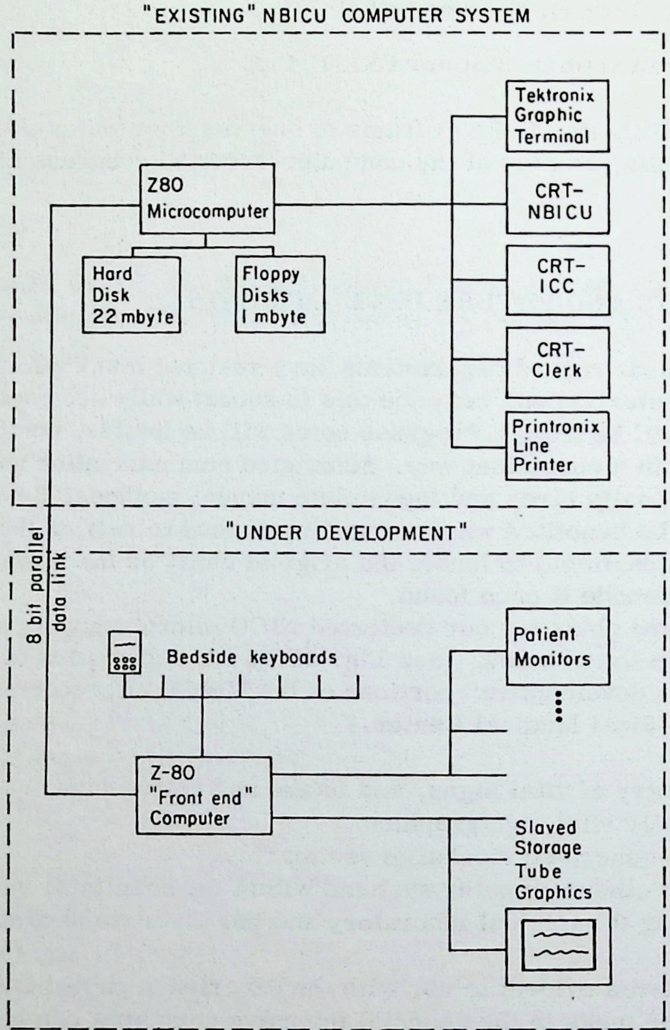


FIGURE 19.18. Schematic representation of the existing NBICU microcomputer system and the one being developed at the Cedars-Sinai Medical Center in Los Angeles.

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