Computerised nutritional data management in neonatal intensive care

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SUMMARY We report a minicomputer based recording, reporting, and research system for patient data management in the neonatal intensive care unit (NICU). It is moderately priced, transportable, and independent of a central computer. It requires only a desk top and standard power supply, and successfully meets the medical documentation, communication, and research needs of the NICU. The first phase of programme development has enabled us to process growth and nutritional data from infants on complex parenteral and enteral nutrition. The system is well suited to medical users and provides a practical interactive data management system with many potential applications in the NICU.

In 1968 it was noted that 'in medical practice, information processing has been badly neglected and little progress made'.¹ Patient data management by computers seemed the obvious solution but despite vast improvements in computing hardware and programming techniques, computer assisted medical care continued to lag behind developments in commercial, industrial, and financial applications over the past decade.

In the neonatal intensive care unit (NICU) the problem of organising and analysing medical information is becoming increasingly difficult, affecting both patient care and clinical research. Important data required to guide clinical decisions is often scattered between bedside flowsheets, medical records, or doctors' pockets. Calculated values, for example the daily caloric or sodium intake, that may be derived from 3 or more nutrient sources are often unavailable or hastily estimated when such questions are raised during ward rounds. A rapid and highly organised method is therefore necessary to monitor patient data on a prospective basis.

Computer utilisation for medical record keeping is not restricted to monitoring individual patients. There is also a need to compare patients who have had similar medical experiences. Clinical research requires the organised compilation of observation and experience—that is accumulation of a data base. The medical records of patients treated in the NICU consist of volumes of paper containing both

descriptive and numerical information that make chart review tedious and laborious. Computerised data is easily and rapidly retrieved for tabulation and statistical analysis.

We report the application of computerised data recording, reporting, and analysis to a study of growth and nutrition in a group of preterm and low birthweight infants requiring complex parenteral and enteral nutritional treatment.

Materials and methods

The hardware of the minicomputer based data management system comprises a Digital Electronics DE-FD II computer system consisting of a LSI 11/23 microprocessor with 64 K bytes of random access memory and 2.04 M bytes of floppy disk storage. Input/output (I/O) is performed by an LA 34 Decwriter IV printer/terminal and an ID-100 8 colour graphics terminal which occupy 2 of the 4 serial I/O ports in the FD11. Software support in the form of the DEC RT-11 V04 operating system provides the underlying structure and system capabilities in conjunction with DEC extended BASIC for high level programming and file handling. The hardware is portable, independent of a central computer mainframe, and requires only a desk top area and standard power supply.

Both neonatologists and computer specialists took part in the planning and development of the system—codenamed NICUDAMAS 1 (Neonatal Intensive

Care Unit DATA Management System). A computer entry flow sheet has been designed that includes selected biographical, clinical, and biochemical information and a daily intake list of 45 nutrient and electrolyte solutions being used in the NICU, of which 30 are given parenterally and 15 enterally. The paediatric registrar has the responsibility for entering the daily intake data on the worksheet and this is then transferred directly on to the computer by either the paediatric registrar or the NICU secretary. A series of questions presented on the ID-100 screen provides prompts for input of data so that the user requires no prior knowledge of computers to run the programme. Safeguards are built into the input programme to preserve the integrity of patient identity and data stored. A programme has been written to generate reports of daily body weight and derived nutritional data in tabular form for the individual patient and this can be correlated with the biochemistry profile of the patient. Application programmes have also been written to summarise the population parameters and facilitate temporal overviews of the population on a daily or weekly basis. Data may also be analysed by graphical display of weekly summaries of any 2 of a choice of 30 parameters, using 2 colours to differentiate between the parameters. To protect patient confidentiality access to stored data is only possible after entry of a password recognised by the computer and known only to the attending neonatologist, the secretary, and the computer programmer who developed the system.

Results

The hardware cost approximately A\$14 000 (≈£8092) and another A\$6000 (≈£3468) was spent on software support. Additional funding for a half time research assistant to develop the programmes resulted in a total project expenditure of A\$25 000 (≈£14 451) during the first year of operation. The results described in this report are based on development work carried out over this 12 month period.

The format of daily data reporting is shown in Fig. 1. Furthermore, a weekly summary of daily reports is printed out for filing as part of the patient's medical records (Fig. 2). The data includes body weight; caloric and fluid intake (total, oral, and parenteral); protein, carbohydrate, and fat intake; non-nitrogen caloric intake per gram of nitrogen intake (NNC:N); and sodium and calcium intake. The variables are accessible in absolute daily quantities as well as on a kilogram body weight basis.

Selected information on the entire study population or for user defined subgroups can also be retrieved from the data base. A summary of the first 25 preterm infants of birthweight less than 1250 g entered into the study is shown in Table 1. Both raw data presented in the traditional tabulated format and statistically processed data (mean (SD)) may be obtained in the abstraction process. Data generated by the output programme for this group of infants includes the minimum postnatal weight expressed as percentage of birthweight (mean (SD), 85 (6%); range, 75–95%) and the age of the infant at minimum weight (mean (SD), 7 (4) days; range 1–18 days). The tabulated data for the rate of postnatal weight gain and changes in body weight for the group are shown in Table 2. Further manipulations of these calculations produced data on body weights grouped into the same postconceptual age that can then be superimposed on the intrauterine growth chart. Some of the computer nutritional intake data for our patient population are shown in Table 3.

The programme also allows users to compare 2 parameters by simultaneously displaying graphically their weekly means and standard deviations on the video screen. Table 4 lists the 30 variables that may be abstracted by the computer and an example of how the data is presented is illustrated in Fig. 3.

Table 1 *Biographic data of 25 infants < 1250 g*

Patient details	Mean (SD)	Range
Birthweight (g)	951 (165)	695–1249
Crown-heel length (cm)	35.8 (2.6)	30.6–39.0
Head circumference (cm)	25.2 (1.9)	22.0–28.3
Gestational age (wks)	29 (2)	24–33

Table 2 *Computed data on postnatal weight gain in 24 infants of birthweight < 1250 g*

Age (weeks)	Rate of weight gain (g/day)		Body weight (g)	
	Mean	SD	Mean	SD
1	–4	34	852	170
2	11	24	870	176
3	16	24	966	215
4	18	30	1062	229
5	19	25	1183	256
6	26	52	1271	264
7	21	32	1389	284
8	23	31	1468	287
9	24	25	1493	231
10	21	26	1549	201

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N I C U D A M A S
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NUTRITIONAL INTAKE FOR 17/18 SEP 1982

BABY XXXXXX                                UR NUMBER XXXXXX

DATE OF BIRTH 14.9.82    GESTATION 25 weeks    BIRTH WEIGHT 872 grams
*****

AGE (days)                4                PROTEIN (gm/kg)                2.4
WEIGHT (grams)            775                CARBOHYDRATE (gm/kg)            11.4
FLUID (ml/kg/d):          FAT (gm/kg)                1.4
    Total                157.4                CALORIES (kcal/kg):
    Oral                 38.7                Total                68.2
    Parenteral           118.7                Oral                25.8
                                                Parenteral           42.4

SODIUM (mmol/kg)          4.7
CALCIUM (mmol/kg)         1.8                NNC:N                165
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Fig. 1 Example of computer printout on daily patient data.

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N I C U D A M A S
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QUEEN VICTORIA MEDICAL CENTRE

NUTRITION TABLE
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BABY KROJITOROVIC                                UR NUMBER 226945

DATE OF BIRTH 14.9.82                                GESTATION 25 WEEKS
*****

Age      Wt      Calories      KCals      Tot.In.      Mls      Na      Ca
days    grams    KCal      /kgWt      Mls      /kgWt  mMol/kg  mMol/kg

*****
1        872      10.8      12.3      69.6      79.8      3.8      .6
2        842      28        32.1      127.7     146.4     1.2      1.7
3        794      44.4      50.9      128       146.7     7.5      1.8
4        775      52.9      60.6      122       139.9     4.3      1.6
5        769      73.3      84        126       144.4     2.9      1.2
6        785      96        110       144       165.1     3.6      1
7        787      90.7      104       136.8     156.8     6.5      .9
*****

*****

Age      Wt      ORAL      Mls      PARENTERAL      Mls      NNC:N
days    grams  /kgWt    /kgWt    /kgWt           /kgWt

*****
1        872      0        0        12.3           79.8      160.9
2        842      .7        1.1       31.4          145.2     162.1
3        794      14.5     21.7      36.4          125       151.3
4        775      22.9     34.4      37.7          105.5     165
5        769      68.8     103.2     15.2          41.2     122.4
6        785      110.1    165.1     0             0         104.3
7        787      104      156.8     0             0         104.3
*****

*****

Age      Wt      Prot      CHO      Fat      Prot      CHO      Fat
days    grams  grams    grams    grams    gm/kg    gm/kg    gm/kg

*****
1        872      .5        2.2      0        .5        2.5      0
2        842      1.2      5.6      0        1.3      6.4      0
3        794      1.9      7.7      .7        2.1      8.8      .8
4        775      1.9      8.9      1.1       2.1     10.2     1.2
5        769      2.6      8.2      3.4       2.9      9.4      3.8
6        785      3.4      8.6      5.4       3.8      9.8      6.1
7        787      3.2      8.1      5.1       3.6      9.2      5.8
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Fig. 2 Example of computer printout on weekly summary of daily patient data.

Table 3 Computed data on fluid and nutritional intake (mean (SD)) in 25 infants of birthweight < 1250 g

Age (weeks)	Fluid (ml/kg/day)	Calories (kcal/kg/day)	NNC:N ratio	Protein (g/kg/day)	Carbohydrate (g/kg/day)	Fat (g/kg/day)	Sodium (mmol/kg/day)	Calcium (mmol/kg/day)	Phosphorus (mmol/kg/day)
1	140 (34)	65 (27)	442 (736)	1.5 (1.4)	11 (3.5)	1.6 (2.0)	2.4 (2.0)	1.9 (0.5)	0.7 (0.8)
2	158 (24)	96 (30)	230 (468)	2.8 (1.3)	13 (4.2)	4.2 (2.8)	3.3 (1.7)	1.9 (0.7)	1.3 (0.9)
3	176 (45)	116 (45)	154 (205)	3.6 (1.4)	13 (4.3)	6.3 (4.2)	3.7 (1.3)	1.8 (1.1)	1.5 (1.1)
4	186 (44)	128 (32)	133 (19)	3.9 (1.1)	14 (4.0)	7.3 (2.2)	3.8 (1.3)	1.9 (1.1)	1.7 (1.1)
5	200 (36)	139 (31)	148 (21)	3.8 (0.8)	15 (3.3)	7.8 (2.1)	3.7 (1.5)	2.0 (1.1)	1.8 (1.1)
6	211 (40)	147 (31)	159 (76)	3.9 (0.9)	16 (3.2)	8.2 (2.2)	3.5 (1.3)	2.1 (1.1)	1.9 (1.2)
7	234 (49)	165 (36)	148 (7)	4.4 (1.0)	18 (3.9)	9.4 (2.3)	3.6 (1.1)	2.5 (1.4)	2.3 (1.4)
8	250 (53)	181 (42)	145 (1)	4.9 (1.1)	19 (4.5)	10.4 (2.3)	3.8 (1.1)	3.2 (2.3)	2.9 (1.9)
9	270 (67)	191 (49)	148 (23)	5.1 (1.5)	21 (5.0)	10.8 (3.2)	4.0 (1.2)	3.5 (2.6)	3.0 (2.1)
10	277 (72)	191 (48)	146 (6)	5.1 (1.3)	21 (5.0)	10.8 (3.2)	4.0 (1.3)	3.7 (2.8)	3.0 (2.1)

NNC:N=non-nitrogen caloric intake per gram of nitrogen intake.

Fig. 3 Example of computer display of patient data correlation (mean (SD) for 25 infants).

Table 4 Patient data available for correlation in graphical form

Serum bilirubin	Body weight (postnatal age)
Serum sodium	Body weight (gestational age)
Serum osmolality	Daily weight gain
Urine osmolality	Volume intake
Blood urea	Volume intake/weight
Serum calcium	% volume of feed (oral)
Serum phosphorus	Caloric intake
Serum alkaline phosphatase	Caloric intake/weight
Serum albumin	NNC:N ratio
Plasma bicarbonate	Protein intake/weight
Plasma base excess	Carbohydrate intake/weight
Haemoglobin	Fat intake/weight
Packed cell volume	Sodium intake/weight
Reticulocyte	Calcium intake/weight
Blood transfusion	Phosphorus intake/weight

NNC:N=non-nitrogen caloric intake per gram of nitrogen intake.

Discussion

Computer assisted patient data management in an NICU has previously been reported from centres with access to large computer facilities.²⁻⁴ The goals of previous studies include the generation of life medical records for documenting trends in perinatal statistics,² the automatic computer production of discharge summaries and letters to community physicians and agencies,³ and the compilation of perinatal data in the conduct of research.⁴ These systems required highly expensive central computer facilities, extensive numbers of technical personnel, and the use of several special-

ised programming languages. Most neonatal units would not have access to such computing resources. Medical computing systems need to be implemented within the stringent technological and financial limitations of a clinical department. Our use of DEC compatible hardware and DEC software as well as the successful implementation of high level application programmes have helped overcome these limitations. Although the merits of such an approach have been reported previously,⁵ it must be emphasised that this is only possible where there is a close working relationship between the staff programmer and NICU staff—especially if none of the clinical personnel has previous knowledge of computers. This liaison is also desirable to extract the maximum benefit from the data base generated.

The use of 'online' computer systems in which patient data is entered onto and retrieved directly from the computer by NICU staff without the need for computer operators to do keypunching have been reported.⁶⁻⁷ The recording of data is divided among the patients' attendants and transferred to the computer by personnel with no formal computer training or experience. Our minicomputer based system has reduced the wastage of staff time and error rates when compared with the previous routine of paediatric registrars working out manually the infants' daily fluid and nutritional intake. It performs a task that these doctors would rather not do for themselves. We believe that the improved completeness and clarity of computer reporting has also optimised patient care. This is the most important rationale for installing a computer, although it is difficult to evaluate objectively given the multifactorial influences on survival rate and quality of survival.

Fluid and nutritional treatment during the preterm infant's stressful adaptation to extrauterine life and in postoperative recovery for infants with abdominal surgical problems are complex. Monitoring of these infants on parenteral nutrition, many of whom also have oral milk supplementation, is unsatisfactory. Conscientious medical record keeping, calculations of derived values of intake which are often from 3 or more nutrient sources, and the accessibility and clear presentation of data are all complicated by a variety of human factors. The use of a computer in parenteral nutrition in infants has been reported.⁸⁻¹⁰ Its application in 2 of the studies was directed to assist the formulation and preparation of parenteral nutrition solutions by the hospital pharmacy.⁸⁻⁹ In 1 report a programme developed to organise and display nutritional data on infants

receiving total parenteral nutrition after surgery used a central computer.¹⁰ Our experience with data processing in infants weighing less than 1250 g who required complex parenteral and enteral nutritional treatment has shown that this can be achieved by using a computer within the NICU. The quality and accuracy of nutritional data is consistent for every patient and requires less time and effort from the NICU staff. The use of the computer to compile a long term data base also serves to facilitate clinical research and obviates the need to do retrospective chart reviews.

In conclusion, the system is attractive because it meets the medical documentation, communication, and research needs of the NICU staff. Its operation consists primarily of the basic computer functions of data collection, manipulation, storage, and retrieval. This patient data management system is therefore an excellent basis from which to begin more challenging data base or diagnostic computing efforts in the NICU.

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