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A Computer Program for Analysis of Anesthetic Records

STEPHEN J. GALLA, M.D.,* ROBERT SCHWARZBACH, B.A.,†
RICHARD BUCCIGROSSI ‡

This paper describes a computer program which we have developed for tabulation and retrieval of information, with emphasis on minimal cost, economy of time, accuracy of data, and simple operation.

* Associate Research Professor.
† Programming Associate.
‡ Programmer.

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METHODS

Coding Forms and Key. Entries from each anesthetic record occupied a single horizontal line on the coding form (fig. 1). The coded contents from individual lines were key-punched on separate Hollerith (IBM) cards, which were the input media for the computer. Subsequently, the information was stored on magnetic tape to simplify retrieval and analysis. (The original coding forms were retained in case the cards or tapes became lost or destroyed.)

A master copy of the coding key (table 1) was posted in the anesthesia office. Although

FIG. 1. Form designed to facilitate coding and keypunching. Each anesthetic record was entered horizontally across the page.

TABLE 1. Coding Key Arranged According to Categories

Sex

M–Male
F–Female

Race

C–Caucasian (white)
N–Nonwhite

Physical status

01–PS 1 (Elective)
02–PS 2
03–PS 3
04–PS 4
05–PS 5
06–PS E1 (Emergency)
07–PS E2
08–PS E3
09–PS E4
10–PS E5

Anesthetist

1–Staff MD
2–Resident or Fellow
3–Graduate Nurse
4–Student Nurse
5–Dentist
6–Medical Student
8–Surgeon or other

Anesthetic Agent

01–Nitrous oxide
02–Halothane
03–Thiobarbiturate
04–Cyclopropane
05–Diethyl ether
06–Divinyl ether
07–Methoxyflurane
08–Ethylene
09–Xylocaine
10–Procaine
11–Pontocaine
12–Neuroleptanalgesic
13–Narcotic
88–Other
99–None

Technique

01–Inhalational
02–Spinal
03–Epidural
04–Nerve block
05–Local infiltration
06–Standby
07–Intravenous
08–Neuroleptanalgesia
88–Other

Relaxant

01–Succinylcholine
02–Curare
03–Flaxedil
04–Syncurine
05–Mylaxen
06–Metubine
88–Other
99–None

Plasma expander

01–Blood
02–Plasma
03–Dextran
04–Rheomacrodex
05–Hydroxyethyl starch
06–Serum albumin
88–Other
99–None

Intubation

1–Orotracheal
2–Nasotracheal
3–Tracheostomy
8–Other
9–None

Respiration

1–Spontaneous
2–Controlled, manual
3–Controlled, mechanical
4–Assisted
8–Other

Operation

01–Intra-abdominal
02–Intrathoracic
03–Extrathoracic (ant. or post.)
04–Cardiovascular
05–Neurosurgical
06–Urological
07–Extremity
08–Perineal
09–Head/neck (surface)
10–Spine and vertebrae
11–Dental
12–Abdominal wall or lower back
88–Other

Special procedure

1–Hypothermia
2–Cardiopulmonary bypass
3–Hypotension, controlled
8–Other
9–None

the choice of the key was arbitrary, the one chosen was limited to items in common usage, Events occurring during the pre- and post-anesthetic course, and complications during anesthesia, were not included in our system. The "anesthetist" category (fig. 1), columns 27–29) indicated the person(s) participating in the anesthetic management. For example, code number 341 meant that the anesthesia was administered by a graduate nurse, assisted by a student nurse and supervised by a staff anesthesiologist. This category should be distinguished from "anesthetist ID number" (columns 75–77), which required a special num-

ber belonging to the person indicated in column 27. Items encountered infrequently were grouped under "other." To minimize confusion, the numbers for "other" (8 or 88) and "none" (9 or 99) were consistent in all categories. The computer was programmed to reject "none" as an error in logic for "primary agent," "major technique," "operation," and "respirations."

Data Processing. An essential feature of the system was the procedure of error checking by the supervisory personnel as well as the computer program. Each anesthetic record was compared with the corresponding entry on the coding form by the secretary. A staff anesthesiologist familiar with the computer operation examined the forms for invalid entries. To minimize errors the coding forms were keypunched and verified by different persons. If punched correctly, the cards were processed by the computer and any coding errors missed by human inspection were identified and printed.

Computer Programming. Figure 2 is a schematic diagram of the sequence used for data processing. Fortran II was chosen as the main computer language because it is available for use with most computers.[1, 2] In addition to the Fortran main program, the system included University of Michigan Assembly Program (UMAP) and Michigan Algorithm Decoder (MAD)[3] subroutines. Cards were processed chronologically and transferred to a magnetic storage tape using a MAD subroutine. To retrieve and rearrange data contained on the storage tape, a UMAP subroutine was used to sort the information and subsequently write it onto a second tape. Finally, a MAD subroutine was used to process the sorted data through the original Fortran program.

The cards were processed monthly by an IBM 7090 computer. If no errors were detected, the input data were printed sequentially under appropriate headings, separated into categories, tabulated, and printed as a monthly summary. In addition, the monthly tabulations were punched onto summary cards for compiling an annual report. At the end of the fiscal year, the storage tape was sorted and data were grouped and tabulated according to each anesthetist's identification number.

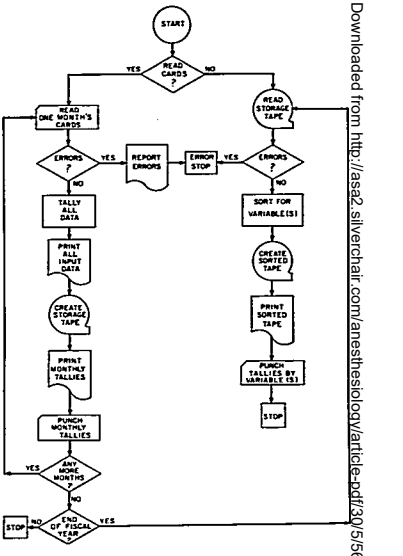

FIG. 2. Schematic diagram of sequence used for data processing by IBM 7090 computer.

RESULTS

Computer Output. Following execution of the program, information describing each anesthetic record was printed sequentially in coded form. Monthly summaries were printed immediately following the listing of cases. Table 2 illustrates the tabulation of anesthetic agents and techniques. Table 3 indicates the utilization of personnel within our department and the amount of time devoted to patients of varying accommodation status.

Time Requirements. Less than one minute was needed to code each record. Checking of the coding forms by the staff anesthesiologist required about three hours per month. The secretary spent approximately 14 hours each month equally divided between comparing anesthetic records with the coding forms and keypunching the cards. Verification of the cards by a keypunch operator in the computation center required about four hours monthly.

TABLE 2. Example of Computer Printout of Anesthetic Agents and Techniques

MONTHLY TOTALS BY CATEGORY JULY, 1967

ANESTHETIC AGENT	Nitrous oxide	Halothane	Thiobarbiturate	Cyclopropane	Diethyl ether
Primary	359	51	14	4	5
Secondary	54	323	34	2	0
Tertiary	2	5	306	0	1
	Divinyl ether	Methoxyflurane	Ethylene	Xylocaine	Procaine
Primary	0	0	0	41	2
Secondary	0	2	0	1	3
Tertiary	0	0	0	1	0
	Pontocaine	Neuroleptanalgesic	Narcotic	Other	None
Primary	64	0	4	11	0
Secondary	0	1	32	2	97
Tertiary	0	0	18	6	216
ANESTHETIC TECHNIQUE	Inhalational	Spinal	Epidural	Nerve block	Local infiltration
Total	423	69	0	16	11
	Standby	Intravenous	Neuroleptanalgesia	Other	
Total	26	9	0	1	

Cost. Computer time for "debugging" programs represented a nonrecurrent cost of about $300. Verification of cards cost $75 annually. Processing data from 6,000 anesthetic records for the general monthly summaries, and for the annual summary for each anesthetist, cost $125 per year (30 minutes of 7090 computer time). Two magnetic tapes at a cost of $50 each provided sufficient space for several years' data.

Frequent Sources of Difficulty. Generally, about 50 errors of various kinds were corrected each month. Illegible entries on the coding forms were a persistent problem which was minimized only by proper indoctrination of new personnel. Difficulties encountered less

TABLE 3. (A) Relative Utilization of Departmental Personnel in Anesthetic Management of Patients; (B) Amount of Time Devoted to Patients of Differing Accommodation Status July, 1967

(A) Anesthetist	Staff	Resident	Graduate Nurse	Student Nurse	Dentist	Medical Student	Other
Primary	45	120	121	133	127	7	2
Secondary	405	24	73	33	14	2	0
Tertiary	89	5	43	18	25	12	1
Total	539	149	237	184	166	21	3

(B) Duration

Total private anesthesia time	60.8 hours	Private patients	42
Total semiprivate anesthesia time	789.4 hours	Semiprivate patients	436
Total ward anesthesia time	126.6 hours	Ward patients	77
Total monthly anesthesia time	976.8 hours	Total	555

frequently were: (1) use of invalid code numbers, (2) reversal of patient's initials or code letters for sex and race, (3) use of incorrect dimensions for weight, and (4) failure to code emergency cases properly.

Discussion

Our main objective in developing a computer program was the acquisition of accurate information for: (1) Blue Cross and Medicare accounting purposes; (2) residents' reports for the American Board of Anesthesiology; (3) morbidity and mortality studies; (4) American Medical Association accreditation surveys; (5) guidance in departmental and hospital planning; and (6) statistical studies of environmental factors in anesthesia.

Although the program was designed to meet specific requirements, it is sufficiently flexible for other applications. Some data processing systems, which have combined the coding form and key, required the expense of special printing and were difficult to check and keypunch. Ordinarily, such a form was completed during the anesthesia. We preferred to have the anesthetist code the case after it was completed.

Alternatively, all coding could have been done by a secretary, but this was less desirable for several reasons: (1) turnover of secretaries in our department is high; (2) they do not fully comprehend anesthetic information; (3) the anesthetist usually had the time needed to code his own cases. Although most errors were eliminated by the computer system, some errors were a continual problem which was controlled only by "human" checking.

Using a computer and magnetic storage tape for data processing had several advantages over a card sorter alone: (1) cross-tabulations were more readily obtainable, (2) visual presentation of data was facilitated, (3) data cards were not subjected to damage from repeated use, and (4) less time was required to retrieve information. The major disadvantages of a computerized system were the initial time and expense involved in "debugging" programs. The annual cost of operating the program was considerably less than would be required to perform the identical functions manually.

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Nomograms for Estimation of Peripheral Resistance and Work of the Heart

J. W. Mostert, M.B.,* R. H. Moore, M.S.,† G. P. Murphy, M.D.‡

We have found it useful to measure intravascular pressures and blood flow during right-heart catheterization in patients with chronic renal failure to obtain objective indices for evaluating the course of the disease and the results of therapy, notably renal transplantation. Although cardiac output determinations are now a common procedure the calculation of useful derived parameters such as peripheral resistance is still laborious. Tables or nomograms would be useful. We therefore made three digital computer printouts of all possible values of cardiac output against all possible mean arterial pressures and the corresponding values for total peripheral resistance and left ventricular work of the heart. In addition,

* Department of Anesthesia, Roswell Park Memorial Institute, Buffalo, New York.
† Department of Biostatistics, Roswell Park Memorial Institute, Buffalo, New York.
‡ Regional New York State Kidney Institute, and Department of Urology, Roswell Park Memorial Institute, Buffalo, New York.