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Computer network for a diagnostic virology laboratory

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Summary

A data base for a large diagnostic virology laboratory is described. The system uses a network of personal computers. It allows the entry, long-term storage, and subsequent retrieval of specimen and patient records (comprising personal identifiers and specimen and result information), and hard-copy results reporting. Sited entirely within the laboratory, the network is not connected to a modem. Within the laboratory there is restricted access to human immunodeficiency virus test results to guarantee patient confidentiality. Retention of a hard-copy of specimen request cards ensures the availability of the original clinical information. The data base is copied on a second file server to facilitate searches, and daily streaming onto magnetic tape provides system protection in the event of hard disc failure. Matching of old and new patient records is done by surname, date of birth, and sex, and therefore duplicate records accumulate when patient names are misspelt on specimen request forms. The system requires further development to speed searches of the data base and to achieve automatic generation of laboratory worksheets. Future goals are the replacement of hard-copy records of clinical information and hard-copy reporting with on-line access to hospital data bases and on-line requesting by and reporting to the clinician.

Clinical virology; Laboratory computer; Data base; Network

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Introduction

Thus far, reports of computerisation in clinical virology laboratories have been few. The solutions adopted have used a large computer (Blomberg et al., 1979) or a microcomputer (Ahmed et al., 1989) sited outside the laboratory, or a large computer sited within the laboratory (Habermehl, 1983). The first two alternatives pose difficulties with restriction of access to confidential data, and all three options are expensive and require the de novo generation of a complex software package. We describe a low-cost self-contained data base developed for a large diagnostic virology laboratory using a network of personal computers. The system is physically sited within the laboratory, yet it provides a comprehensive patient and results record and allows standardised hard-copy reporting of results.

Materials and Methods

Laboratory

The North Manchester Virus Laboratory provides comprehensive diagnostic virology and chlamydiology services to a population of approximately one million in north and central Manchester. Seventeen hospitals and approximately 300–400 general practitioners submit specimens. In 1991, 52405 specimens were received, 11255 for virus detection, 14595 for chlamydia detection, and 26555 for virus serology. Tests in routine use include virus isolation in cell culture, respiratory virus antigen detection by immunofluorescence (Morris and Semple, 1990b), cytomegalovirus immediate early antigen detection (Morris et al., 1987), the polymerase chain reaction for the diagnosis of herpes simplex virus encephalitis (Klapper et al., 1990), adenovirus immune dot-blot (Killough et al., 1990), chlamydial isolation in cell culture and immune dot-blot (Mearns et al., 1988), electron microscopy including serotyping of faecal adenoviruses (Wood et al., 1989), rotavirus enzyme-linked immunosorbent assay, hepatitis A, B, C and D virus and human immunodeficiency virus (HIV) serological tests (Morris et al., 1990a), rubella and toxoplasma screening and serological diagnosis, complement fixation tests, screening for recent B19 parvovirus infection (Rayment et al., 1990), and cytomegalovirus antibody tests on organ donors (Morris et al., 1990c).

After receipt the specimen request card follows the specimen round the laboratory. This allows a written record to be made on the card of the investigations planned by a senior member of laboratory staff and of the test results.

Description of computer hardware and software

The network comprises six work stations each with a keyboard, a visual

display unit, and a personal computer (three Vectra CS with 2 megabyte (MB) memory) and one Vectra RS20 with 25 MB memory (Hewlett Packard, Sunnyvale, USA), one V386 with 25 MB memory and one VPC II with 2MB memory (Victor Technologies, Stockholm, Sweden). There are three Epson SQ2500 printers. Long-term data storage is provided by a Hewlett-Packard™ 486/25T file server, and back up data copies are made on magnetic tape (Inmac, Runcorn, UK) using a tape streamer (Cipher Data Products, Singapore). The software is Paradox™ 3.0 tailored for its purpose by applications written in the Paradox Application Language™ (Borland International, Scotts Valley, USA). Networking is provided by eight-bit cards and uses Netware™ software (Novell Inc. Utah, USA)

Results

General description of data base

Repetition is avoided by splitting the data into four parts: (1) 'patient': surname, forename, date of birth, sex; (2) 'specimen': laboratory number, specimen type, consultant or general practitioner, hospital, hospital number, ward; (3) 'result': test, virus, result; and (4) 'memo': memorandum related to result. The patient and other data are stored in three linked sets of tables: (1) 'reception': data for each specimen entered when the specimen arrives in the laboratory; (2) 'post': temporary storage for specimen details being transferred from reception into the main tables; and (3) 'main': main storage tables for 'patient', 'specimen', 'result', and 'memo'. The data on the main tables are interlinked (Table 1).

TABLE 1
Links between data in main tables

PATIENT	Specimen 1	Result 1a — Memo 1a
		Result 1b — Memo 1b
		Result 1c — Memo 1c
	Specimen 2	Result 2a — Memo 2a
		Result 2b — Memo 2b
		Result 2c — Memo 2c
	Specimen 3	Result 3a — Memo 3a
		Result 3b — Memo 3b
		Result 3c — Memo 3c

Entry of new specimen details

On arrival each specimen is given a unique laboratory number in the form X91/number. X defines the specimen type: I for virus isolation or detection, S for serology, or C for chlamydia isolation or detection. The year is abbreviated as its last two integers (e.g., 1991 as 91). The number is chosen from a consecutive series starting at 1 for the first specimen in each calendar year.

Specimen details are entered onto a screen (Fig. 1) which has fields for surname, forename (or initials), sex (M, F, or ?), date of birth (in day, month, and year format), laboratory number, specimen type, initials of consultant or general practitioner, hospital, hospital number, and ward. If only the age is known, this is entered in the date of birth field and flagged with an 'E' (estimated). The computer then records the date of birth as the first of January in the year of birth. More than one specimen can be entered for the same patient without the need to start a new data entry sequence. Once the specimen data are stored in the 'reception' tables, they are accessible by surname to all terminals in the network. An specimen entry in the 'reception' table may be edited or deleted from only one terminal at a time.

Posting

Patient and specimen data in the temporary input 'reception' tables can be transferred to the 'main' storage tables by posting. All specimen records with duplicate numbers are kept within the 'reception' tables. Other specimen data are transferred from the 'reception' to the 'post' tables where matching of each specimen record with data on the 'main' tables is attempted. Any specimen found to have a patient surname, sex and date of birth identical with that of a patient already in the main data base will not be transferred from the 'post' to

```
ENTER          [Ctrl] -[<-] & [->] Patient, [S]eek Lab. No.          16.10.92
Specimen       [Del]ete, [Esc]ape, [Ins]ert                          .....
                                                                  OTHER A9295002
ZPatient DDDDDDDDDDDDDDDDDDDDDD RECEPTION DDDDDDDDDDDDDDDDDDDDSpecimen Entry?
3                                                                   16.10.92 3
3       Surname   OTHER                    Forename  AN                    3
3                                                                         3
3       Sex       M                        D.O.B.    31.01.11              3
3                                                                         3
3                                                                         3
3Specimen DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD3
3                                                                         3
3 Lab. No.    Spec.  Cons.  Hospital        Hospital Num.     Ward         3
3                                           (Marks)                       3
3 I92 98888   U      AA     GRH             007               PM          3
3                                                                   16.10.92 3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDD[F1] For Hospital Fill InDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Fig. 1. Specimen data entry screen

the 'main' tables, but will be offered to the operator. He or she checks whether the two patients are the same (if necessary by checking the current specimen request card against any previous specimen cards stored in the laboratory files). If they are identical the records of the two patients are merged.

The autoposting programme is designed to run overnight and is the standard method for transferring specimen data from the 'reception' tables to the 'main' tables. Five functions are performed. First, three print-outs of the entries for that day are produced in surname order, one for serology, one for virus isolation, and one for chlamydia detection (Fig. 2a). These are filed in one of

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Report in Patient Surname Order of All Files

1.1.91

Patient Surname	Forename	S	D.o.B.	Lab No	Hos-pital	Ward	Spec	Comments
Cotty	Charlotte	F	09.01.46	I91 0004	MAN	1	C/S	
Grey	George	M	17.04.01	I91 0002	007	9	T/S	
McInnes	Mary	F	14.11.49	I91 0005	DON	2	C/S	
Ray	Ruth	F	02.08.22	I91 0001	MIT	1	U	
Smith	Sidney	M	08.02.53	I91 0006	EVE	10	U/S	
Tyms	Thomas	M	04.07.62	I91 0003	LON	4	BAL	

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Report in Laboratory Number Order of All Files

1.1.91

Lab No	Patient Surname	Forename	Hos-pital	Ward	Spec	Remarks	Date
I91 0001	Ray	Ruth	MIT	1	U		
I91 0002	Grey	George	007	9	T/S		
I91 0003	Tyms	Thomas	LON	4	BAL		
I91 0004	Cotty	Charlotte	MAN	1	C/S		
I91 0005	McInnes	Mary	DON	2	C/S		
I91 0006	Smith	Sidney	EVE	10	U/S		

Fig. 2. Examples of entries in virus isolation day books: (a) surname entry, (b) laboratory number entry.

three office day books and used as a back-up to the computer record for the identification of patient entries. These office day books are also used to record by hand the issuing of reports (as a parallel to the results record on the computer) and to detail the subsequent destination of the request card (files or further tests). Second, three other hard copies of the entries for that day are produced in laboratory number order, again one for each specimen category (Fig. 2b). After filing in one of the three laboratory day books, they are used to provide a back-up to the computer for specimen records. In addition, all results on each specimen are recorded by hand in the relevant laboratory day book to provide a parallel record to the results entered in the computer. Third, all specimen records with duplicate laboratory numbers are left in the 'reception' tables for editing the following morning. Fourth, any specimen record with a match of its patient details with an existing patient record is left in post file for manual posting. All other records are transferred to the 'main' tables. Fifth, back-up copies of the 'main' table are made onto magnetic tape.

Results and memo entry

Results may be entered for any specimen stored in the 'main' tables. The relevant patient record is retrieved from the 'main' tables using one of the query functions (see below). The format for results entry is 'test, virus, result'. Once a result has been inserted an individualised memorandum may be attached to it. Identical results for a series of specimens with consecutive laboratory numbers can be entered without the need to retrieve all the patient records, and the same result can also be attached to other specimens identified on the basis of a laboratory number even if the result is additional to another result already recorded for that specimen. If, during the entry of a batch of results, a patient record is being altered or having a result attached by another user, the result and the specimen number will be displayed on the screen at the end of the procedure. When a malfunction occurs in a batch results entry procedure, the exercise is abandoned but the operator can begin again from the point where the programme was blocked.

Results printing

Results can be printed in several report styles, including 'virus, test, and result', messages in words (e.g., 'insufficient specimen', 'possible virus isolated'), or reports of tests on multiple specimens (for examples, see Fig. 3). Each report is printed in duplicate, validated by a senior technician, and then handwritten interpretative comments are added by a senior medical or scientific member of staff prior to issue. One copy is sent to the clinician, and one copy is attached to the specimen request card to provide a hard copy for storage. The results for a batch of specimens may be printed immediately after insertion into the 'main' tables using the batch entry method described above. If a problem with the printer arises during a batch print procedure, printing of

Name	Hospital	Hospital No.
OTHER	NINEWELLS	12345678
First Name	Ward	Consultant By
AN	10	ABC DS
D.O.B. Sex		Report Date
1.01.11 F		14.10.92

Specimen T/S Lab. No. I92_99999 Date Rec'd 13.10.92

Virus	Test	Result
Virus	isolation	NEGATIVE

North Manchester Regional Virus Laboratory, 061-741-5200
Booth Hall Childrens Hospital Manchester, M9 2AA. VIROLOGY

Name	Hospital	Hospital No.
OTHER	NINEWELLS	12345678
First Name	Ward	Consultant By
AN	10	ABC DS
D.O.B. Sex		Report Date
1.01.11 F		14.10.92

Specimen NPA Lab. No. I92_99999 Date Rec'd 13.10.92

Immunofluorescence Test For Respiratory syncytial virus

Was POSITIVE

ISOLATION RESULT TO FOLLOW

North Manchester Regional Virus Laboratory, 061-741-5200
Booth Hall Childrens Hospital Manchester, M9 2AA. VIROLOGY

Fig. 3. Standard report styles. (a) virus isolation; (b) antigen detection by immunofluorescence (above); (c) serology, multiple tests on two specimens (see page ?????).

the results can be reinstated without needing to repeat the results insertion process.

Output options

These produce printed lists of the stored data for internal use within the laboratory. The data is selected on date range. There are three programmes. 'Specimen' offers options of surname or laboratory number order and then a range for the date selection. 'Results' includes all tables in the database, the data being presented in surname order and selected on date range. 'Day logs' produces duplicate day logs for a selected date in surname or laboratory number order.

Search and query

These programmes allow access to all data on the 'main' tables. The information for each patient is displayed in a format of four levels, patient, specimen, result, and memo (Fig. 4). Searching for a patient record is by surname and forename or by laboratory number. To exclude a misspelling of the surname entered on the main table or on the current request card an

Name		Hospital	Hospital No.
OTHER		NINEWELLS	234913
First Name		Ward	Consultant By
AN		4	ABC DS
D.O.B.	Sex		Report Date
1.01.11	F		15.10.92

	Lab. No.	S92_02152	S92_04093
	Specimen	VB	
	Date Rec'd	29.01.92	21.02.92
Antibodies To:-	Test		
Cytomegalovirus	(CF)	<1/10	1/80
Herpes simplex virus	(CF)	<1/10	<1/10
Mycoplasma pneumoniae	(CF)	<1/10	<1/10

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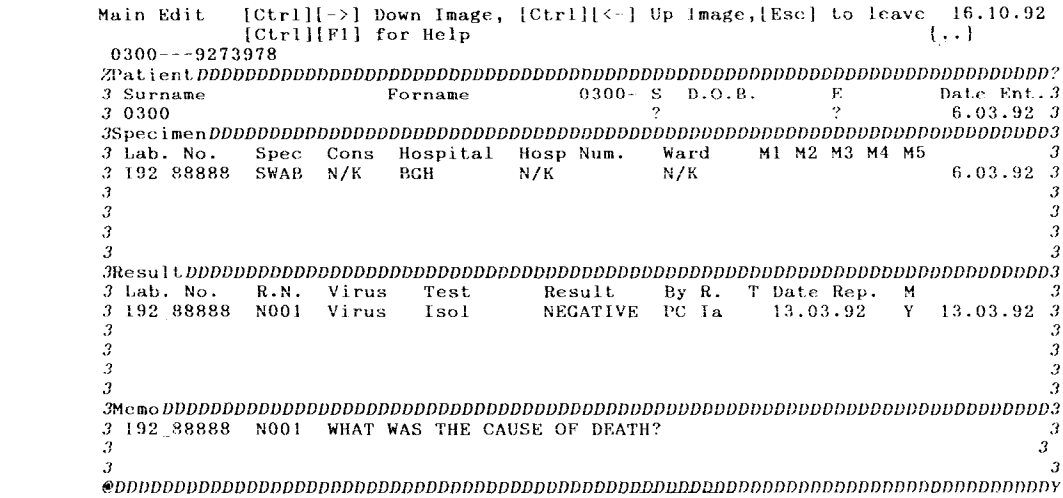

Fig. 4. Patient record screen.

alphabetical list of the surnames of all patients on the data base can be accessed at any point and searched manually in an attempt to identify the patient required.

Other functions

Dictionary tables hold the reference lists for possible entries of hospital, result, virus, test and report style (for example, see Fig. 5). Each list can be accessed as a superscreen when appropriate to the current activity, and a copy printed using the reporting programme. The number of specimens received from each hospital between defined dates may be derived. A full range of data editing facilities is available. Patient records belonging to identical patients can be merged if not matched during posting.

Confidentiality

The network is contained entirely within the laboratory. There are no outside links, all inputs being from specimen request cards and all outputs through hard copy reports. Reports of human immunodeficiency virus (HIV) antigen and antibody tests are only displayed on the screen or printed when the operator is one of a restricted group of laboratory personnel using a personalised set of passwords. A separate set of report styles for HIV is available (not shown).

@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY

Report Reference Table : Hvirus

12.10.92 Standard report Page 1

Abbreviation	Full Name
.	.
Ad	Adenovirus
Ad 21	Adenovirus type 21
Ad 41	Adenovirus type 41
Ad1	Adenovirus type 1
Ad10	Adenovirus type 10
Ad14	Adenovirus type 14
Ad15	Adenovirus type 15
Ad2	Adenovirus type 2
Ad3	Adenovirus type 3
Ad31	Adenovirus type 31
Ad4	Adenovirus type 4
Ad40	Adenovirus type 40
Ad5	Adenovirus type 5
Ad6	Adenovirus type 6
Ad7	Adenovirus type 7
Ad8	Adenovirus type 8
AdF	Group F adenovirus
Antig	Antigen
Astro	Astrovirus
Calici	Calicivirus
CB1	Coxsackie B virus type 1
CB2	Coxsackie B virus type 2
CB3	Coxsackie B virus type 3
CB4	Coxsackie B virus type 4
CB5	Coxsackie B virus type 5
CB6	Coxsackie B virus type 6
Ch	Chlamydia
CHLAM	CHLAMYDIA
CMV	Cytomegalovirus
Corona	Coronavirus
CoxA16	Coxsackie A virus type 16
CoxA21	Coxsackie A virus type 21
CoxA7	Coxsackie A virus type 7
CoxA9	Coxsackie A virus type 9
DeltAb	Hepatitis delta virus ANTIBODY
DeltAg	Hepatitis delta virus ANTIGEN
EBcAg	EB virus capsid antigen
Echo 5	Echovirus Type 5
Echo11	Echovirus type 11

Fig. 5. Example of dictionaries: part of virus list.

DISCUSSION

Our computer network was designed to achieve certain goals. These were matching new specimens with existing patient records, access to several years stored patient records by name or specimen number, patient confidentiality, and hard copy reporting of a broad range of diagnostic virology tests. Patient matching relies on identity of surname, date of birth, and sex, and has the advantage of an operator check on the match. In retrospect other matching criteria could perhaps have been included as patients whose date of birth is not

supplied and misspelt names are not matched. At present duplicate records for the same patient may easily be created, but many are later paired when new and old request cards are matched or when the computer data base is compared with the stored request cards. However, if the matching criteria were more loose than now, much more operator time would be spent rejecting mismatches.

Reliable access to several-year patient records has been achieved by using a combination of a high capacity fileserver with a multiread hard disk and magnetic tapes. So far, 3-year records are maintained. The disadvantage of having such as large data base within our current network is slowness of access (up to 1 min to search for a patient record by name). Resolution of this problem will require updating of the personal computers and the current eight-bit network cards with more powerful hardware and sixteen- or thirty-two bit network cards.

The design of our data base, a network of personal computers and a fileserver, means that the hardware can all be sited within the laboratory. Access is restricted to laboratory personnel, with only hard copy external links. The problems of confidentiality posed by using a main-frame (Blomberg et al., 1979) or micro-computer (Ahmed et al., 1989) sited outside the laboratory are thereby avoided, as are the cost of installing a large computer in the laboratory and of developing dedicated software (Habermehl, 1983).

The generation of hard copy reports represents a major labour-saving achievement in a laboratory performing a large number of different tests. Prior to computerisation, our laboratory reports were either hand- or type-written. A photocopy was then sent to the clinician and the original retained in the laboratory files. Now duplicate reports are generated automatically. The availability of a large number of different report styles allows the reporting and printing of virus isolation, serology, and chlamydia detection results using a single report format. Memoranda can be added at the time of report printing, though this facility is currently little used because each memorandum must be typed individually.

We decided at the outset that retention of a hard copy of all specimen request cards and reports filed in patient name order was essential. Our view has not changed. Our current hand written request cards often contain much semi-legible material which cannot be deciphered immediately. The correct spelling of names may only become apparent after comparison with stored hard-copy records, and clinical details are often only comprehensible to a medically qualified member of staff who cannot check all cards before entry. If inappropriate tests are done or patient records are not paired because of misinterpretation of information on the request card, the oversight is more easily corrected if a hard copy is available. Also the laboratory staff can continue to educate clinicians on the need for accurate, legible information on request cards and the same staff can also learn from their own mistakes. Medicolegal difficulties are much more easily avoided.

When the requesting of laboratory tests is computerised in all the hospitals

and health care centres we serve, on-line input of specimen and patient details and reporting will be possible. The arguments in favour of retaining hard copy data storage and reporting (e.g., illegible handwritten request cards) will no longer be valid. Our current software is well-suited to interlinking with other computer networks and data bases. If all health care units maintain long-term patient records, we may no longer need our own long-term data storage facilities. On-line access to reliable clinical information enterred by the referring clinician onto a hospital data base linked to our computer network will allow senior staff in the laboratory to validate results on a visual display unit and add interpretative comments before on-line reporting of the results. Automated linking of a report with a particular memorandum or interpretative comment, and use of codes to speed the entry of memoranda and comments, will also be possible. The need for confidentiality will nonetheless remain. On-line test and results requesting must only be available to appropriate health care staff via a set of personalised passwords. Access to HIV requests and results will have to be restricted to senior medical staff by a similar mechanism.

In the future the facilities of our computer network should be expanded to include automated generation of laboratory work sheets. Currently work sheets are generated manually from lists of investigations hand-written on the specimen request cards. When the network has on-line access to clinical information, automation of this process could save considerable technician time. Other future developments should include greater facilities for the abstraction of data sets for a given time period. Targets include all positive results (helpful for preparing weekly returns to the national epidemiological surveillance centre), all results for a particular test, and all results for a particular virus. Also, simple statistical analyses of these data would be valuable. At present epidemiological research in our laboratory has to be done using manually prepared data (Bates et al., 1993), and statistical analyses performed without use of the laboratory computer.

In conclusion, we developed a computer network for a large virology laboratory providing a comprehensive range of diagnostic tests. Long-term storage of demographic and results data, retrieval of that data, and hard-copy reporting have been achieved without sacrificing confidentiality. Relatively simple modifications to the system should allow on-line requesting and reporting, and sophisticated epidemiological analysis of the stored data.

References

Ahmed, K., Mahony, J., Stiles, C., Castriciano, S. and Chernesky, M. (1989). A clinical virology database for a regional virology service. J. Virol. Methods 26, 255–268.

Bates, P.R., Bailey, A.S., Wood, D.J., Morris, D.J. and Couriel, J.M. (1993) Comparative epidemiology of rotavirus. subgenus F (type 40 and 41) adenovirus, and astrovirus gastroenteritis in children. J. Med. Virol. 39, 224–228.

Blomberg, J., Mattson, J., Borjesson, B., Hast, S., Anderson, P. and Holm, K. (1979) VIRUS - A laboratory information system for clinical virology. Methods Inform Med 18, 207 214.

Habermehl, K-O. (1983) Data storage and retrieval in clinical virology. In: Waterson, A.P. (ed) Recent Advances in Clinical Virology, Vol. 3, Churchill Livingstone, Edinburgh, 1983: 263–276.

Killough, R., Klapper, P.E., Bailey, A.S., Sharpe, I.R., Tullo, A. and Richmond, S.J. (1990) An immune dot-blot technique for the diagnosis of ocular adenovirus infection. J. Virol. Methods 30, 197–204.

Klapper, P.E., Cleator, G.M., Dennett, C. and Lewis, A.G. (1990) Diagnosis of herpes encephalitis via Southern blotting of cerebrospinal fluid DNA amplified by polymerase chain reaction. J. Med. Virol. 32, 261–264.

Mearns, G., Richmond, S.J. and Storey, C.C. (1988) Sensitive immune dot-blot test for diagnosis of chlamydia trachomatis infection. J. Clin. Microbiol. 26, 1810–1813.

Morris, D.J., Lomax, J., Craske, J., Longson, M. and Fox, A.J. (1987) Effect of centrifugal enhancement of infectivity on the rapid detection of human cytomegalovirus in cell culture by immunofluorescence using a monoclonal antibody to an immediate early nuclear antigen. Serodiagn. Immunother. 1, 141–152.

Morris, D.J., Corbitt, G. and Crosdale, E. (1990a) Effect of switching from first- to second generation enzyme-linked immunosorbent assays on screening for human immunodeficiency virus antibody. Serodiagn. Immunother. 4, 217–220.

Morris, D.J. and Semple D. (1990b) Rapid detection of respiratory syncytial virus in nasopharyngeal aspirates by direct immunofluorescence using monoclonal antibodies. Serodiagn. Immunother. 4, 53–57.

Morris, D.J., Klapper, P.E., Crosdale, E. and White, J. (1990c) Screening of bone marrow and kidney transplant donors and recipients for cytomegalovirus antibody by commercial latex agglutination or competitive enzyme-linked immunosorbent assays. J. Virol. Methods. 30, 339–342.

Rayment, F.B., Crosdale, E., Morris, D.J., Pattison, J.R., Talbot, P. and Clare, J.J. (1990) The production of parvovirus capsid proteins in Escherichia coli and their potential as diagnostic reagents. J. Gen. Virol. 71, 2665–2672.

Wood, D.J., de Jong, J.C., Bijlsma, K. and van der Avoort, H.G.A.M. (1989) Development and evaluation of monoclonal antibody-based immune electron microscopy for diagnosis of adenovirus types 40 and 41. J. Virol. Methods. 29, 241–250.