Appropriate Technology

Laboratory equipment—where are the tools to do the work?

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The call for appropriate technology in medical laboratory sciences, especially for equipment, is becoming widespread and urgent. In developed countries new technology has led to a proliferation of complex tools and a tendency to overinvestigate patients. Such tools have been introduced more in response to demand than need, with the tacit help of manufacturers. For many health authorities this costly new technology is becoming difficult to sustain.

In the Third World it is a question not of financial cuts threatening existing services but of how to establish a service at all when the tools do not exist or, if they are available, are often too expensive. It is a disturbing fact that (with few exceptions) none of the commercial manufacturers' profits have been used to research appropriate tools for use in developing countries.

Which investigations?

Before considering which tools are necessary in a district hospital laboratory in a developing country it is helpful to look at the range of tests that are currently undertaken in these laboratories (table I). Not all the tests listed will be required in every district hospital laboratory, and it may be necessary to include others. Tests should always be selected according to local health needs, cost effectiveness, training and experience of laboratory staff, reagents and equipment needed, and whether a reliable referral system is available. Owing to high cost, lack of facilities, and inexperienced staff, many district laboratories find it difficult or impossible to estimate serum electrolyte concentrations or to carry out culture and sensitivity tests.

It is important to have close links with a regional laboratory to ensure the reliability of the peripheral service and to allow more complex biochemical and serological tests to be carried out. It may also be possible to refer microbiological specimens—for example, sputum for the culture of *Mycobacterium tuberculosis*, urogenital swabs for *Neisseria gonorrhoeae*, and throat swabs for group A *Streptococcus*. All specimens must be collected and preserved correctly.[1] A referral system usually operates between the provincial or central laboratory and the peripheral laboratories for the examination of smears for malignant cells, histological examination of biopsy specimens, and reporting of bone marrow aspirates.

Table II shows the range of equipment needed to perform the investigations listed in table I. Guidelines for the specifications of these items of equipment may be found in a document published by the World Health Organisation.[2] For descriptions and ordering information about most of the equipment in this list, readers are referred to chapters two, three, and five in volume 1 of a *Medical Laboratory Manual for Tropical Countries*.[1]

The equipment listed in table II is neither extensive nor complex, yet few peripheral laboratories have these basic resources—a fact which underlies a recent statement from the World Health Organisation that "... every aspect of the supply and operation of health care laboratory equipment in developing countries is seriously deficient . . . a rigorous programme of design, supply, maintenance, and repair must be established in all countries."[3]

Equipment must be designed for its environment

An instrument that has been designed to operate in a laboratory in a developed country by trained scientists with regular servicing by skilled engineers is destined for a short and difficult life in the district laboratory of a developing country. Even if it survives the journey, the circuit shorting, mould growing and heat of the wet season, the dust of the dry season, and the intermittent electrical supplies, its end will surely come when a vital part cannot be obtained, or the laboratory assistant or local car mechanic takes a look inside and attempts to repair it without recourse to a maintenance or service manual. Equipment for use in a developing country peripheral laboratory must meet certain criteria. It must:

(1) Be rugged, and able to operate reliably under extremes of heat, humidity, and drought.

(2) Be fitted with a voltage stabiliser if indicated.

(3) Be designed for easy use by those with limited technical training and experience.

(4) Come ready supplied with essential spare parts and a clearly written and illustrated maintenance and service manual.

Basic care and preventive maintenance of laboratory equipment should be included in the syllabuses of all laboratory workers, and every developing country should establish a centre for servicing equipment and evaluating the suitability of new equipment. These and other aspects of equipment design and care have been discussed fully at length.[3]

Battery or mains operated equipment

Many district hospitals in developing countries are without 24 hour mains electricity and are served only by a generator. This may operate only when the main hospital autoclave is used, when major surgery is performed, and for a few hours each evening to light the wards when darkness falls. (Kerosene lamps take over when the generator "sleeps.") Even if the hospital does have mains electricity, electrical supplies are often intermittent and of irregular voltage. Thus it is necessary to find alternative power supplies and adapt and redesign equipment to operate from these. Solar powered cells are expensive, so a 12 volt lead acid storage battery, rechargeable from the mains when operating, or possibly from a windmill, is the power pack of choice.

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TABLE I—*Laboratory tests performed in district hospitals in developing countries**

Investigation	Usual method
Blood	
Haemoglobin concentration	Colorimetric
Total white cell count	Counting chamber
Differential white cell count and red cell morphology	Examination of stained thin film
Platelet count	Counting chamber
Reticulocyte count	Examination of stained preparation
Packed cell volume	Centrifuge
Mean cell haemoglobin concentration	Calculation from haemoglobin concentration and packed cell volume
Erythrocyte sedimentation rate	Westergren
Bleeding time	Filter paper method
Clotting time	Lee and White tube method
Blood grouping	Slide (tile) and tube methods
Compatibility testing	Room temperature saline, antihuman globulin (if available) or albumin at 37°C
Antibody testing:	
To investigate syphilis	Rapid plasma reagin (RPR) card test or Venereal Diseases Reference Laboratory (VDRL)
To investigate enteric fever	Slide and tube agglutination
To investigate brucellosis	Slide and tube agglutination
Blood glucose concentration	Colorimetric
Blood urea concentration	Colorimetric
Serum bilirubin concentration	Colorimetric
Total protein concentration	Colorimetric
Malaria parasites	Field's stained thick smear, Giemsa stained thin smear, buffy coat stained smear
Trypanosomes	Field's stained thick smear, direct microscopy of plasma in microhaematocrit
Microfilariae	Lysed blood preparation, direct microscopy of plasma in microhaematocrit, haematoxylin and eosin smear
Borreliae	Field's stained thick smear
Screening test for kala-azar	Formol gel test
Sickle cell test	Sodium metabisulphite slide test, sodium dithionite tube test, Romanowsky stained blood film
Cerebrospinal fluid	
Cell count	Counting chamber
Cell differential	Romanowsky stained smear
Pyogenic bacteria	Gram smear
Tubercle bacilli	Ziehl-Neelsen smear
Protein	Sulphosalicylic acid test
Globulin screen	Pandy's phenol test
Glucose estimation	Colorimetric
Trypanosomes and Mott cells	Direct microscopy and Giemsa smear
Skin	
Smears for *Mycobacterium leprae*	Ziehl-Neelsen
Snips for *Onchocerca volvulus*	Saline preparation
Scrapings for fungi	Potassium hydroxide preparation
Sputum	
Smear for tubercle bacilli	Ziehl-Neelsen
Detection of eosinophils	Eosin preparation
Paragonimus eggs	Saline preparation
Exudate and discharges	
Pus for gonococci	Gram smear
Vaginal discharge for *Trichomonas* and *Candida*	Saline preparation, Gram smear if parasites and yeasts are not detected
Ulcer exudate for donovanosis	Giemsa smear for Leishman-Donovan bodies
Chancre fluid for syphilis	Dark field for spirochaetes
Mucopus from mycetoma or eumycetoma (granules)	Potassium hydroxide preparation
Urine	
Cells, casts, bacteria, crystals	Direct microscopy (Gram of sediment if pus cells present)
Protein	Reagent strip test or sulphosalicylic acid test
Glucose	Reagent strip test or Benedict's test
Ketones	Reagent strip or tablet test, or nitroprusside test
Bilirubin	Fouchet's test
Urobilinogen	Ehrlich's tube test
Haemoglobin	Reagent strip test
Pregnancy test	Slide test to detect human chorionic gonadotrophin (HCG), tube test to semiquantify HCG
Schistosoma haematobium	Direct microscopy for eggs and red cells, or membrane filtration, Schisto-kit, also a test for protein
Faeces	
Parasites	Direct microscopy for amoebae, cysts, larvae, and eggs, using saline, eosin, and iodine. Concentration technique for eggs, especially of schistosomes
Occult blood	Peroheme-40 (British Drug Houses (BDH) test)
Other	
Lactase deficiency	Benedict's test or Clinitest to detect sugar (lactose). Strip test to detect low pH

* Not all the tests listed will be required in every district hospital laboratory, and it may also be necessary to include others.

TABLE II—*Equipment required for district laboratories in developing countries*

Major equipment	*Additional equipment*	
Microscope	Bunsen burner or spirit lamp	Slides and coverglasses
Centrifuge	Hot plate	Syringes, needles, blood lancets
Heat block or water bath	Insulated container	Forceps
Haemoglobin meter or colorimeter (or both)	Differential cell counter	Tourniquet
Water filter	Hand tally counter	Blood taking sets
Water still	Counting chambers	Dressings
Steriliser	Interval timer	Cleaning materials
Refrigerator	Dispensing and pipetting devices	Markers
Balance	Racks and trays	Thermometer
	Staining equipment	Glass and plastic ware to collect, test, and disinfect specimens, and to prepare and store stains and reagents
	pH meter or narrow range pH papers	

At present the range of laboratory equipment that runs off a battery is limited and usually expensive, but there is a new company—Primary Health Equipment Ltd—that has been formed recently to design and produce inexpensive laboratory equipment, especially battery operated equipment, for use in peripheral laboratories in developing countries.

Details of essential equipment

MICROSCOPE

The microscope is the most important tool in the laboratory, but although the range is vast, there is at present no instrument that is ideally suited for use in a district laboratory in a developing country. Such a microscope should be rugged, tropicalised, and able to be serviced by the user. An instrument equipped with a mirror and battery operated lamp is required for hospitals without mains electricity. Daylight is not sufficient for use with the oil immersion objective, especially when the microscope is binocular. A low priced, ruggedly built range of microscopes is the Zenith range, available from Primary Health Equipment Ltd. The binocular quadruple nosepiece model is shown in figure 1. It is equipped with a mechanical stage, condenser and iris, and range of optics to give magnifications up to × 1350. It costs £247 complete with case and three objectives. Available accessories include a dark ground condenser (price £19), a lamp unit for mains electricity supply, a 60 × oil immersion lens, and other optics. Monocular instruments are also available from £150, complete with optics, mechanical stage, mirror, and case.

For those who require a compact portable microscope the small in focus McArthur microscope is available from McArthur Microscopes Ltd. It costs £494 and comes complete with optics. A range of accessories is available.

CENTRIFUGE

This is required to separate whole blood to obtain serum for cross matching, serological tests, and biochemical tests and to obtain sediments of cerebrospinal fluid, urine, and other specimens. For most laboratories a centrifuge with a 6 × 15 ml or 8 × 15 ml head is adequate; it should have a variable speed control and a relative centrifugal force of not less than 2300 *g*, be fitted with a brake, incorporate essential safety features, and be supplied with spare carbon brushes and a clear instruction manual. (A swing out rather than an angled head is preferable, although this may be less readily available and more expensive.)

Hettich Zentrifugen Company manufactures a 12 volt battery operated, variable speed, 6×15 ml angle head centrifuge (EBAIII 2009), price £192. A similar 6×15 ml mains electricity model is also available. The mains model is supplied in the United Kingdom by Arnold Horwell Ltd. One of the lowest priced, small, swing out and angle head variable speed centrifuges, equipped with brake and safety features, is the MLW T51 model available from Clandon Scientific Ltd (fig 2). It costs £310, plus £72·91 for an 8×15 ml swing out head, or £41·96 for a 4×15 ml head. The maximum speed is 2450 *g* (4200 rpm) for the eight tube head and 2800 *g* (4500 rpm) for the four tube head. A 24 place, mains operated microhaematocrit centrifuge is available from Hawksley and Sons Ltd, price £265.

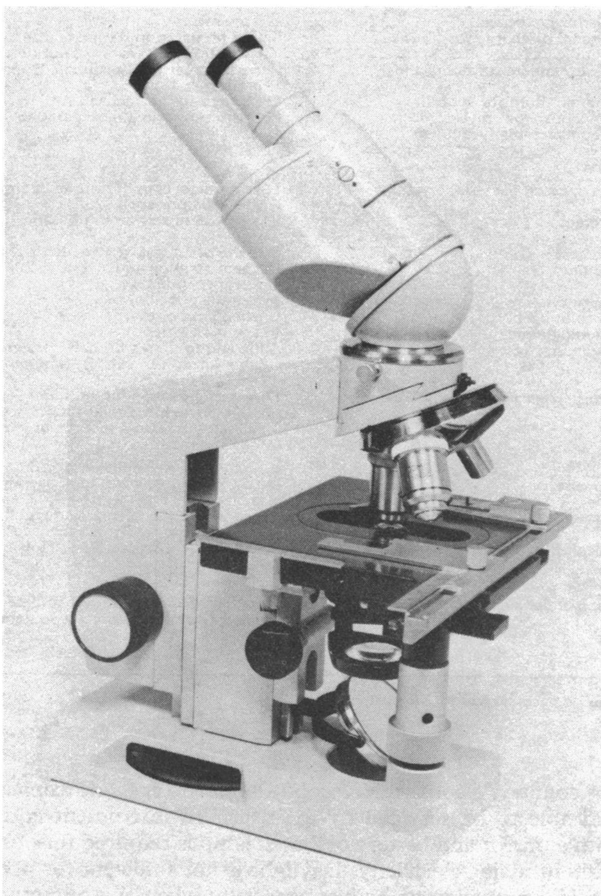

FIG 1—Zenith binocular microscope.

HEAT BLOCK OR WATER BATH

The main use of a heat block or water bath in a district laboratory is for cross matching blood safely. It should be controlled thermostatically and operate from a 12 volt battery and mains electricity supply. A small low priced battery/mains portable heat block/incubator will soon be available from Primary Health Equipment Ltd. The block holds 6×12 mm diameter tubes and 3×16 mm diameter tubes, but individual laboratories may request the size of holes they require if the standard block is not suitable. With the block removed and lid in place, the heating unit functions well as an incubator for keeping specimens warm during transit to the laboratory. The unit will cost about £49·55, complete with block. A transformer to operate the unit from the mains electricity supply will also be available.

HAEMOGLOBIN METER

An ideal haemoglobin meter would be one that is low priced, reliable, accurate, rugged, tropicalised, and capable of operating from inexpensive solar cells or rechargeable batteries (or mains electricity); it should be one that gives a direct readout and does not require the blood to be diluted. The ideal has yet to be designed, but the small, Delphi haemoglobin meter (fig 3) fulfils many of these criteria. It gives a direct readout and may be easily calibrated for either the oxyhaemoglobin or cyanmethaemoglobin method. It is rugged, and reports from several developing countries have shown it to be reliable. It operates from a 9 volt battery or from a mains electricity supply through a transformer. It will soon be available in the United Kingdom from Arnold R Horwell Ltd and is expected to cost about £330.

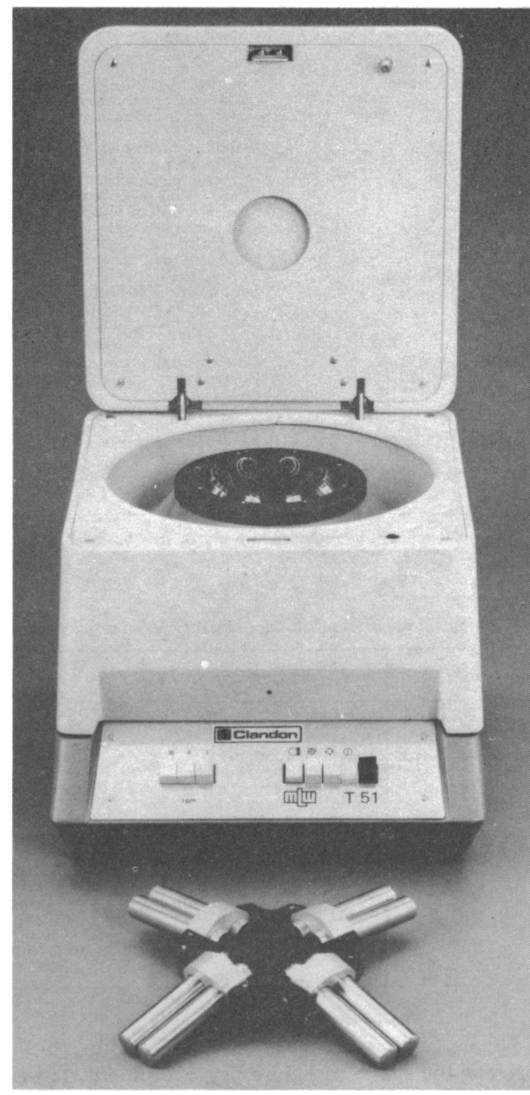

FIG 2—MLW T51 centrifuge showing angle head in position and swing out head for 8×15 ml tubes.

COLORIMETER

Like the haemoglobin meter, the ideal colorimeter for developing countries is not yet available, but an instrument that is in production and has been used successfully in developing countries is the Corning model 252 filter spectrometer (fig 4). It uses a diode system and may be operated from a 12 volt battery or mains electricity supply and has an inbuilt voltage stabiliser. The wavelength range is 400-700 nm with a filter band width of 40 nm. It is available from Corning Medical Ltd and costs £225, complete with lamp, cuvette holder, and 100 plastic cuvettes. The 12 volt battery lead is extra and also the filters, each of which costs £10. The filters are resistant to moulds and mounted in sealed units. Filter No 540 nm is required for estimating haemoglobin (cyanmethaemoglobin method), total protein (Biuret), and serum bilirubin (Jendrassik and Graf); No 520 nm for blood urea (diacetyl monoxine) and creatinine (Jaffe); and No 600 nm for blood glucose (o-toluidine) and serum albumin (bromocresol green). The use and maintenance of the instrument are clearly described in a good instruction manual.

FIG 3—Delphi battery and mains haemoglobin meter with accessories.

FIG 4—Corning battery and mains model 252 colorimeter.

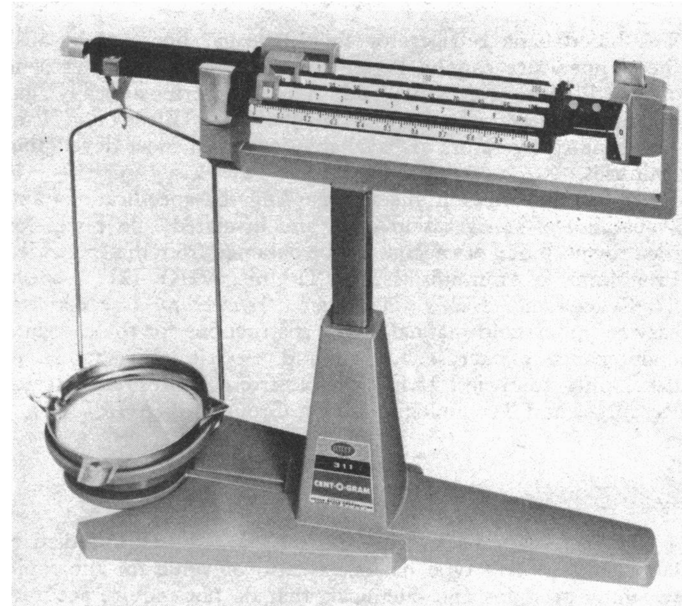

FIG 5—Ohaus balance with 0·01 g sensitivity and 311 g capacity.

WATER STILL

A water still is needed to provide distilled water to make chemical reagents and reference solutions. For preparing water to make stains a simple porcelain filter candle can be used. The pharmacy is likely to need a still to produce pyrogen free water, so it may be possible to share the same still between the two departments. A low cost 3 kW still with a capacity of about 4 l/hour, is the Quickfit model W14S, available from J Bibby Science Products Ltd, price £295. It has the advantage of requiring a minimum of cooling water. An automatic cutout operates to prevent overheating if the water supply fails, and there is also a thermal fuse and a preset constant levelling device. The still is easy to clean, and spare parts are readily available. Although the Quickfit still requires mains electricity, sufficient distilled water can usually be made during the hours when the hospital generator is operating.

A new water still for use in developing countries has been designed recently by the Central Scientific Instrument Organisation in India. For details readers should write to the director of the organisation.

STERILISER

In a district hospital the sterilising needs of the laboratory are usually met by the central sterilising supply unit. If, however, the district laboratory is performing culture and sensitivity tests it will require its own autoclave. A range of portable autoclaves that may be operated from mains electricity or a gas or a Primus stove are available from Arnold and Sons Ltd. Six models are available in two sizes; 29 cm diameter × 27 cm depth, and 28 cm diameter × 50 cm depth. They range in price from £149·80 to £501·71. The stand for the gas ring or burner is £21·13. Autoclave control indicator tubes or time steam temperature (TST) strips are available from Albert Browne Ltd.

REFRIGERATOR

A refrigerator is essential for storing reagents, antisera, and some test kits and for preserving patients' sera and other specimens. A separate carefully controlled refrigerator is essential for the safe storage of blood. Gas or kerosene operated refrigerators are required in hospitals without mains electricity.

The blood bank refrigerator should be gas operated because the temperature can be better controlled than in a kerosene operated unit. Kerosene and reliable thermostatically gas operated refrigerators are available from Electrolux Ltd. Kerosene refrigerators are available locally in most developing countries.

Product information sheets regarding the specifications and availability of refrigeration units and insulated cold boxes for the transportation of vaccine can be obtained from the Expanded Programme of Immunisation (EPI) Unit, WHO, 1211 Geneva 27, Switzerland. *How to look after a refrigerator* is a concise, easy to understand manual giving instructions for the care and maintenance of kerosene, gas, and electric refrigerators in developing countries. It is available from Appropriate Health Resources and Technologies Acting Group Ltd (AHRTAG).

BALANCE

A balance with a sensitivity of 0·01 g is required in a district laboratory. A trip type balance is also of value for the rapid weighing of stains and chemicals that do not require accurate weighing. The Ohaus balances with integral weights are suitable and inexpensive. The Ohaus model 311 with a sensitivity of 0·01 g and capacity of 311 g (fig 5) costs £98. The Ohaus Havard trip balance with a sensitivity of 0·1 g and capacity of 2000 g costs £97. Both balances are available in the United Kingdom from Gallenkamp and Co Ltd.

INCUBATOR

For laboratories that can carry out culture and sensitivity tests an incubator is required. In the low priced range of incubators that operate from a mains electricity source the Gallenkamp economy incubator model INA-300 size 1 (575 × 590 × 490 mm high) is well insulated and fitted with an inside door and a hydraulic type thermostat. It is available from A Gallenkamp Ltd, price £297. A low priced thermal plastic 12 volt battery or mains incubator 444 × 368 × 444 mm high is available from GQF Manufacturing Company, priced about $180.

Conclusion

Appropriate equipment for use in the district hospital laboratory in developing countries is urgently needed. Such equipment must be designed according to medical needs and the surroundings in which it will be used. It must be reliable, robust, and easy to use by those with a limited technical background. It must also be produced at a price that such countries can afford. Much redesigning, training, sharing of resources, and transfer of technology to developing countries are needed if the majority of the world's sick are to have access to investigations essential to diagnosis and the major communicable diseases are to be controlled.

This series will continue in early autumn.

References

[1] Cheesbrough M. *Medical laboratory manual for tropical countries.* Volume 1, 1981;volume 2, 1984. Tropical Health Technology Ltd, Doddington, Cambridgeshire. The manuals are produced on a low cost basis to assist developing countries.

[2] World Health Organisation. *Specifications for production and/or assembly of basic laboratory equipment.* Geneva:WHO, 1983.

[3] World Health Organisation. *Supply, maintenance and repair of health care laboratory equipment in developing countries.* Geneva: WHO, 1983. (LAB/83.8.)

Manufacturers

Primary Health Equipment Ltd, Machno, Church Street, Stilton, near Peterborough, Cambs PE7 3RF, UK. The company was formed and is managed by Mr Alan Riley, a qualified design engineer and member of the consultative group for appropriate technology in the field of health laboratory technology.

McArthur Microscopes Ltd, Landbeach, Cambridge, Cambs CB4 4ED, UK.

Hettich Zentrifugen, Andreas Hettich, Postfach 4255, D-7200 Tuttingen, West Germany.

Arnold R Horwell Ltd, 73 Maygrove Road, West Hampstead, London NW6 2BP, UK.

Clandon Scientific Ltd, Lyson's Avenue, Ash Vale, Aldershot, Hampshire GU12 5QR, UK.

Hawksley and Sons Ltd, 12 Peter Road, Lancing, Sussex.

Corning Medical Ltd, Halstead, Essex CO9 2DX, UK.

J Bibby Science Products Ltd, Tilling Drive, Walton, Stone, Staffordshire ST15 0SA, UK.

Central Scientific Instrument Organisation, Chandigarh, India.

Arnold and Sons Ltd, Bentalls, Basildon, Essex SS14 3BY, UK.

Albert Brown Ltd, Chancery House, Abbey Gate, Leicester LE4 0AA, UK.

Electrolux AB, International Division, S-10545, Stockholm, Sweden.

AHRTAG, 85 Marylebone High Street, London, W1M 3DE, UK.

A Gallenkamp Ltd, PO Box 290, Technico House, Christopher Street, London EC2P 2ER, UK.

GQF Manufacturing Company, PO Box 1552, Savannah, Ga 31402, USA.

What are the risks of permanent developmental damage occurring in an infant with persistent vomiting, weight loss, and dehydration between the ages of 5 and 12 weeks?

If we assume the vomiting is gastrointestinal—that is, not neurometabolic and therefore associated with an abnormal brain—the possibility of brain damage depends mainly on the degree of dehydration but is also influenced by methods used to correct it. In the 1950s, when milk formulas were not so highly modified as they are today, a child with vomiting (and diarrhoea) might have been given milk with too big a solute load and suffered hypernatraemic dehydration and subsequent brain damage; this would be rare today but might occur with injudicious intravenous treatment. In the United Kingdom severe dehydration is unlikely to result from vomiting alone, as one assumes that a child persistently vomiting would be brought to the attention of a paediatrician fairly soon. Dehydration associated with vomiting and fever in a child with congenital heart disease may occasionally lead to cortical venous thrombosis because of a high packed cell volume. Brain damage from vomiting due to pyloric stenosis is rare, and no case in Seshia's series of acute brain damage[1] or the National Encephalopathy Survey followed dehydration solely due to vomiting (M Bolan, personal communication). If a child recovers fully from an episode of dehydration delayed neurological problems are unlikely.—S H GREEN, senior lecturer in paediatrics and child health, Birmingham.

[1] Seshia SS, Seshia MMK, Sachdeva RK. Coma in childhood. *Dev Med Child Neurol* 1977;19:614-28.

Correction

Appropriate technology: Anaesthetics

We regret that there were two errors in this article by Dr F N Prior (9 June, p 1750). In table I the controlled ventilating concentration of halothane should have read 0-0·5%, and in the section on equipment the first sentence of the second paragraph should have read, "All these conditions are met by two anaesthetic machines—namely, the EMO (Epstein, Macintosh, Oxford) and the OMV (Oxford Miniature Vaporiser). . . ."