Glossary

Lasix	Frusemide.
B.P.	Blood pressure.
E.C.G.	Electrocardiogram.
J.V.P.	Jugular venous pressure.
i.m.	Intramuscular.

Appointments of Speakers

Dr. W. Dewi Rees, M.D., M.R.C.G.P., General Practitioner (Llanidloes, Mont.)

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New Appliance

pH Profile of Gut as Measured by Radiotelemetry Capsule

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Mr. S. J. Meldrum, Dr. B. W. Watson, and Mr. H. C. Riddle, of the Department of Medical Electronics, and Dr. R. L. Bown and Dr. G. E. Sladen, of the Department of Gastroenterology, St. Bartholomew's Hospital, London E.C.1, write: The relative inaccessibility of the lower gastrointestinal tract and the semi-solid nature of its contents precludes the ready measurement of luminal pH by conventional techniques. It is possible to measure the pH of small-bowel contents obtained by aspiration[1] but it has been shown that the pH of these contents does not always agree with the true luminal pH as measured by intraluminal electrodes.[2] Normal colonic contents cannot be aspirated and, as shown below, stool pH is a poor reflection of intracolonic pH. A radiotelemetry capsule ("radio pill") has been developed which is swallowed by the subject and continuously measures the pH of surrounding gut contents.

A radiotelemetry capsule for measuring pH was described by Jacobson and MacKay.[3] It used as the transducer a copolymer resin which changed its dimensions with pH. The extremely slow response time of this device made it unsuitable for routine clinical use. A similar telemetry capsule later described by Nöller[4] used an antimony electrode as the transducer. This device suffered from serious drift problems, as antimony is oxidized quickly in the presence of body fluids. The drift and short life of this device make it suitable for use only in the stomach and small intestine.[5]

The pH telemetry capsule described here was developed from the original specification of Watson and Kay[6] and measures pH by means of a glass electrode. This responds to true changes in hydrogen ion concentration, and the stability of the device is such that it may be used to investigate pH throughout the entire gastrointestinal tract.

Description of Capsule

The device consists of a glass pH electrode, a transistor oscillator, and a replaceable mercury battery encapsulated in a polyacrylate body. A silver chloride reference electrode is situated in the battery cap of the capsule. The overall measurements are 10 mm in diameter and 25 mm long. The potential difference developed between the glass and reference electrodes is proportional to the hydrogen ion concentration of the fluid in which the device is immersed, and this voltage is used to modulate the frequency of the radio transmitter. The device thus transmits at a frequency proportional to the pH of its surroundings. A circuit diagram is shown in Fig. 1.

The response of the device in various buffer solutions is shown in Fig. 2, indicating the linear response between pH 1 and pH 12. When swallowed the device is at body temperature, but in situations where this is not the case the temperature error introduced is of the order of 0·1 pH unit per °C. The life of the capsule is limited to about 10 days by diffusion of electrolyte from the reference cell, but this is more than enough for transit through the human alimentary system. The end-cap containing the reference electrode may be replaced and the device used again.

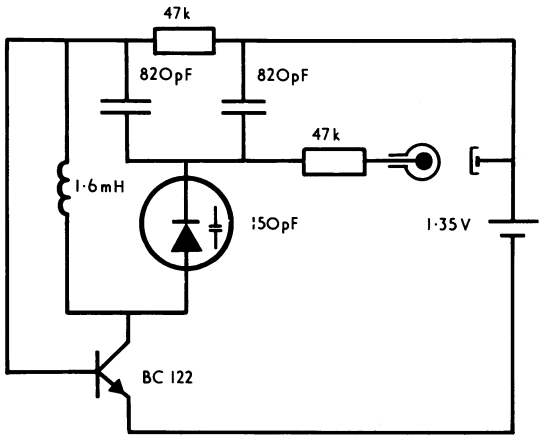

FIG. 1—Circuit diagram of telemetry capsule.

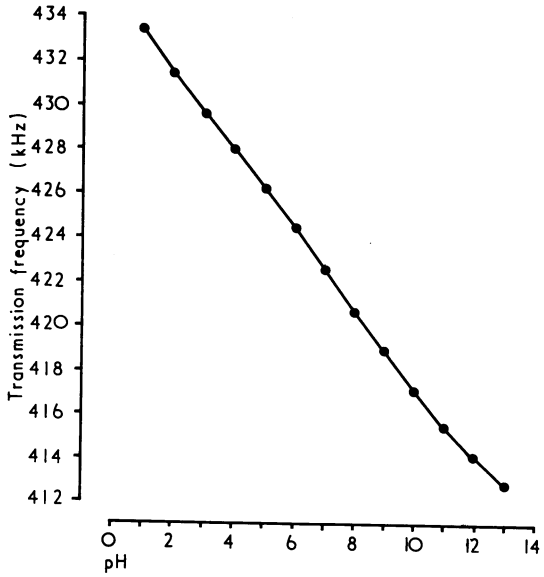

FIG. 2—Transmission frequency of capsule at various pH values.

If the capsule is carefully stabilized before calibration the baseline drift is less than 0·1 pH during each clinical study. It is essential to ensure that the glass electrode is properly activated by immersing it in 0·1 N HCl for at least 24 hours and also that the mercury battery has been run down on to the flat part of its voltage time characteristic. Where failure of the device occurs moisture has usually penetrated the capsule, reducing the voltage developed by the glass electrode, leading to a reduction in the frequency shift per unit pH change. The pH capsule forms part of a radiotelemetry system previously developed for recording a range of variables in the intestinal tract.[7] An F.M. receiver, developed for use with these devices and operating in the band 270-570 kHz, is used to receive the radio signals and process the information for presentation on a chart recorder. The capsule has been investigated for stability over many hours in buffer solutions at body temperature.

Methods of Use

Two normal subjects and seven patients with miscellaneous gastrointestinal disorders who were thought not to have a disturbance of intraluminal gut pH were studied.

The radio pill was swallowed shortly after breakfast and the pH recorded at hourly intervals during the day and at longer intervals during the night. During each measurement period the subject placed the receiving aerial on the abdomen in an optimal position as indicated by a signal-strength meter on the receiver. The pH was then recorded for five minutes on a pen recorder precalibrated in pH units and running from the start of the investigation. In addition the pH of the bolus of faeces passed with the capsule was measured at 37°C. Little restriction was made on physical activity or diet. The radio pill was recalibrated on recovery and corrections were made for baseline drift occurring during the study.

Anatomical localization of the device was performed by abdominal radiography at spaced intervals until recovery. The number of *x*-ray films depended on the transit time but usually a total of four or five were needed.

In order to validate the use of the radio pill in the semisolid contents of the colon three specimens of semiformed faeces and one of ileostomy effluent were incubated at 37°C. Into each specimen were placed a radio pill and three dialysis bags of the type described by Wrong *et al.*[8] The bags were then recovered at intervals after at least 12 hours to allow equilibration and the pH of the dialysate as measured by a standard pH electrode (Radiometer Copenhagen, pH meter 27) was compared with the pH as determined simultaneously by the radio pill in the faeces.

Result

The pH profile of the gut from the stomach through the small and large bowel to that of the consequent faeces is shown in Fig. 3. The shaded area is bounded by the extremes of values observed in each region of the gut in the nine subjects. In the stomach the range observed was considerable, though no subject was achlorhydric (pH less than 3·0 was observed at some stage in all subjects). In one subject an extreme range of 1·5-7·3 was observed before and after food. As the radio pill passed into the duodenum a rapid rise in pH occurred, and this continued at a slower rate along the jejunum and ileum until the ileocaecal region was reached. Here in most subjects a small fall in pH occurred, though in seven of them the pH was above 7·0. In the colon and rectum the pH remained about neutral but a rapid fall occurred in freshly-passed stools, presumably the result of continuing fermentation.

The comparison between the pH of faeces as determined by the dialysis bags and by the radio pill is shown in the Table. The maximum discrepancy was 0·2 pH unit.

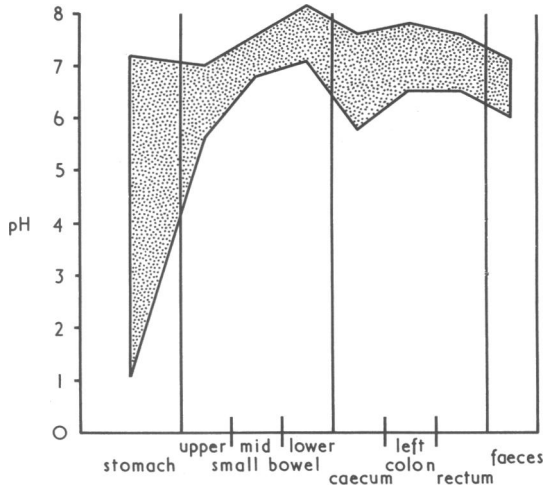

FIG. 3—Profile of pH in the gut. Shaded area represents extremes of values observed in nine subjects.

Comparison of pH as measured simultaneously by Radio Capsule and Faeca Dialysis

	pH of Faecal Dialysate	pH as Determined by Radio Capsule
Ileostomy effluent ..	4·7	4·5
	4·7	4·7
	4·7	4·7
	4·7	4·8
Stool A	6·0	5·9
	5·0	5·1
	5·0	5·0
Stool B	5·3	5·2
	5·3	5·2
	5·2	5·1
Stool C	4·8	4·6
	4·8	4·6
	4·3	4·2

Discussion

The radio pill remains sufficiently stable to allow an accurate pH measurement of the entire length of the gut. The measurement procedure is well tolerated by patients and requires little restriction of activity. After an initial explanation all the subjects were able to record pH by themselves. As the radio pill is usable for at least 10 days prolonged observations may be made in a localized area of the gut if the capsule is tethered by a thread.

We have defined the pH profile along the gastrointestinal tract in normal subjects. The observations in the small bowel are in broad agreement with those already published.[1] Intracolonic pH, however, has not previously been reported in man under normal physiological conditions. The close agreement between the pH measured by the radio pill and that in the dialysates suggests that true values of pH were obtained. The intracaecal pH was lower than that of the rest of the colon. This value was less than 7·0 in only two subjects, whereas in experiments on animals mean values of 6·1 have been reported.[9] The pH of stools is invariably lower than that of faeces within the rectum and falls rapidly on standing; consequently the measurement of faecal pH gives a poor reflection of intracolonic pH.

The radio capsule may provide a simple method for the study of fermentative processes in the lower bowel. This may be relevant to the diagnosis of various forms of sugar malabsorption in the investigation of obscure diarrhoeal diseases. In an analagous situation we have shown that lactulose, an agent used in the treatment of hepatic encephalopathy, produces a sharp reduction of ileocaecal pH, which is probably related to its therapeutic effect.[10]

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The pH telemetry capsules are available from Rigel Research Limited, The Vineyard, Richmond, Surrey.

References

[1] Fordtran, J. S., and Lochlear, T. W., *American Journal of Digestive Diseases*, 1966, **11**, 503.
[2] Benn, A., and Cooke, W. T., *Scandinavian Journal of Gastroenterology*, 1971, **6**, 313.
[3] Jacobson, B., and MacKay, R. S., *Lancet*, 1957, **1**, 1244.
[4] Nöller, H. G., in *Proceedings of Second International Conference on Medical Electronics, Paris*, ed. C. N. Smyth, Springfield, Thomas, 1959. p. 296.
[5] Connell, A. M., and Waters, T. E., *Lancet*, 1964, **2**, 227.
[6] Watson, B. W., and Kay, A. W., *Biomechanics and Related Bio-Engineering Topics*, ed. R. M. Kenedi. Oxford, Pergamon Press, 1965.
[7] Watson, B. W., *World Medical Electronics*, 1966, **4**, 277.
[8] Wrong, O. A., Metcalf-Gibson, A., Morrison, R. B. I., Ng, S.T., and Howard, A. V., *Clinical Science*, 1965, **28**, 357.
[9] Bourke, E., Milne, M. D., and Stokes, G. S., *Gut*, 1966, **7**, 558.
[10] Bown, R. L., Sladen, G. E., Clarke, M. L., and Dawson, A. M., *Gut*, 1971, **12**, 863.

Any Questions?

We publish below a selection of questions and answers of general interest

Treatment of Acne Keloid

What is the most effective treatment for acne keloid?

The treatment of acne keloid (sycosis nuchae) is a difficult problem that is not encountered often nowadays. The results of treatment with *x*-rays has not impressed me. A colleague has had the affected area excised by a plastic surgeon, irradiating the graft to prevent further keloid formation; but this may be a mistaken idea since it is believed that the keloid forms in response to follicular infection or irritation from abnormal hairs that penetrate the follicle wall or both.

I would recommend trying long term oral and local antibiotic treatment (appropriate to the sensitivities of the organisms cultured from the pustules) combined with 0·2% fluocinolone acetonide (Synalar Forte) under polythene occlusion (or Haelan tape) before contemplating excision and grafting, which is a last resort.

Hazards of Cleaning Buildings

What medical hazards face workers engaged in cleaning buildings (1) with water sprays and acid; (2) by high-speed blastings? Are there any statutory regulations covering this type of operation?

The use of water sprays and acid (normally a very dilute solution of hydrofluoric acid) has been adopted increasingly in recent years as a means of cleaning buildings. The acid, which attacks siliceous material, loosens the grime with the superficial layer of the brick or stone facing and these are removed after an interval by the water spray. Hydrofluoric acid is hazardous mainly before it is diluted for use. Splashes in the eye will require copious and prolonged irrigation with water to minimize injury. Skin contact from the acid should be treated on the spot by applying a paste of light magnesium oxide 1 part and glycerine (B.P.) 1·5 parts to the affected area. Waterproof clothing should be worn by the operator.

Cleaning by high speed blasting is also common. The blasting agent may be sand or a non-siliceous abrasive and it can be applied either dry or wet. Alternatively, a high-speed power-driven carborundum wheel or cone may be used to remove the grimy surface of the stone. Dry cleaning methods produce much dust.

The dangers from a blasting or abrasive removal of dirt will depend on whether a dry or wet method is adopted, whether siliceous or non-siliceous abrasive materials are used, and the nature of the building fabric. Wet methods are the safest though the material removed soon dries and produces dust. Where possible, a non-siliceous abrasive should be used. Cleaning a building built of natural sandstone or granite is more hazardous than if it is built of brick or Portland stone (natural or reconstituted). Despite these obvious hazards, evidence of pneumoconiosis is meagre. Experience has shown that many workers in this trade tend to be engaged on a temporary basis for a specific contract or if employed permanently do this work intermittently. Furthermore, the removal of industrial grime from buildings is essentially a practice which has become fashionable only in the last 20 years or so.[1]

The Construction (General Provisions) Regulations 1961 will normally apply to this type of work.[2] Among their provisions are requirements "to provide and use suitable respirators to prevent inhalation of dust of such a character and to such an extent as to be likely to be injurious to health" (Reg. 20); and "to provide suitable goggles or effective screening to protect the eyes of persons employed on such processes as dry grinding of surfaces of metal, stone, concrete or similar materials by means of a wheel or disc driven by mechanical power" (Reg. 52).

[1] Ministry of Public Buildings and Works, *Building Research Station Digest No. 113, Cleaning External Surfaces of Buildings*. London, H.M.S.O., 1970.
[2] Ministry of Labour, *The Construction (General Provisions) Regulations 1961*, S.I. No. 1580. London, H.M.S.O., 1961.

Triple Vaccine Reactions

An infant had two days of fever and restlessness after its first injection of triple vaccine at six months. At 8 months diphtheria/tetanus vaccine was given. While there was no general reaction the baby had a severe local reaction at the injection site. On both occasions oral poliomyelitis vaccine was given. What should be done about the third immunization due at 12 months?

The infant has received two doses of diphtheria and tetanus toxoids, 8 weeks apart, and therefore should have protective levels of both diphtheria and tetanus antitoxins in the serum. This could be confirmed in the laboratory. The two reactions, one pyrexial and one local, were probably due to different factors and it is likely that a third injection at 12 months would be without complications. Nevertheless, since immunization against whopping cough was abandoned after the first dose of triple vaccine, there is little to be gained by giving another dose of combined diphtheria/tetanus vaccine at 12 months to an infant who is probably already immune to those two diseases. A booster dose should be given however at school entry age.