CONTINUOUS MEASUREMENT BY RADIO-TELEMETRY OF VAGINAL pH DURING HUMAN COITUS

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Summary. The use of the pH-pill has allowed continuous monitoring of vaginal pH during human coitus. In the case of a couple of normal fertility, there was an immediate buffering by seminal plasma so that the vaginal pH changed in 8 sec from pH 4·3 to pH 7·2. In the case of a couple of low (male) fertility, the immediate effect of the arrival of semen in the vagina was a change from pH 3·5 to pH 5·5. A similarly small change in pH occurred when the seminal volume of a fertile male subject had been depleted, by repeated ejaculation, to 1·5 ml. At this pH (5·5), spermatozoa are generally immobilized.

It has been possible to alter normal fertility, as judged by postcoital tests for sperm motility, by the introduction of a pH 3·6 buffer solution into the vagina before coitus. In this latter experiment, the vaginal pH immediately after ejaculation was 5·0 and, after 2 hr, had reached pH 5·4.

These results *in vivo* suggest that the vagina is not the hostile environment hitherto imagined, since the normal ejaculate readily overcomes the vaginal acidity by its powerful buffering action. Low seminal volume, with or without a concomitantly low sperm count, and artificial changes in vaginal environment by buffer solutions may affect fertility.

INTRODUCTION

Numerous investigators have studied the effect of acidity upon the motility of human spermatozoa *in vitro* (Muschat, 1926; Randall & Muschat, 1926; Baker, Ranson & Tynen, 1937; Shedlovsky, Belcher & Levenstein, 1942; Blackshaw & Emmens, 1951; Masters, 1960; Diasio & Glass, 1971), whilst similar experiments in the bull have been reported by Smith & Asdell (1940), Easley, Mayer & Bogart (1942), Anderson (1946) and Blackshaw & Emmens (1951).

Tyler (1959) described experiments involving the removal of human cervical mucus at varying times *post coitum* for microscope studies of sperm motility and pH. The first studies *in vivo* on the effect of vaginal acidity upon the motility of human spermatozoa were reported by Masters (1959, 1960) and Masters & Johnson (1961) and were reviewed by Masters & Johnson (1966). These pioneer

studies demonstrated the importance of the vaginal environment in fertility, but involved the intermittent measurement of vaginal pH *post coitum* by the use of glass electrodes.

We now report the first continuous measurements made possible by the advent of radio-telemetry.

MATERIALS AND METHODS

The apparatus consisted of a pH-sensitive telemetry capsule, a loop aerial, a radio receiver and a pen recorder. The telemetry capsule has been developed from the original specification of Watson & Kay (1965) and consists of a glass pH electrode, a transmitter circuit and a mercury battery encapsulated in a 'Perspex' body. A silver chloride reference electrode is included in the replaceable battery cap, the complete unit measuring 25×9 mm when assembled. Its use intravaginally is quite acceptable since it closely resembles an ordinary therapeutic pessary in size and can be inserted by the female into the posterior fornix of the vagina. Furthermore, the use of telemetry means an absence of wires, in contrast to conventional pH electrodes, so that the subjects could use the apparatus in the privacy of their own homes (see Fox, Wolff & Baker, 1970).

The capsule transmits in the band 400 to 500 kHz and responds linearly between pH 1 and 12. Before use, it is calibrated in buffer solutions at 37° C. Should the vaginal temperature differ from this value during the course of an experiment, the error introduced is of the order of 0.1 pH unit per degree C. Once activated, the life-time of the device is about 10 days and, over this period, the baseline stability is typically 0.1 pH unit per day. A Frequency Modulation receiver developed for use with these capsules is employed to receive the radio signals and process the information for presentation on a chart recorder. The transmitter and receiver (Plate 1) form part of a system previously developed for studies in gastroenterology (Watson & Kay, 1965) and are now commercially available (Rigel Research Ltd, Richmond, Surrey).

The subjects for this investigation were (a) a couple of known fertility, the male having a sperm count of about 100×10^6 /ml and a seminal volume of 5 to 6 ml/ejaculate, after at least 4 days abstinence. They have four children, and the female partner had been taking the oral contraceptive 'Orlest 28' (containing 1 mg norethisterone and 0.05 mg ethinyloestradiol) for the previous 12 months and throughout the experiments; (b) a couple of low fertility, the male having a sperm count of $<4 \times 10^6$ /ml and a seminal volume of <2 ml per ejaculate, after at least 4 days abstinence. They have one child by AIH, and a further conception has since taken place by the same means. The female partner was not on any medication during the experiments.

The composition of the pH 3.6 buffer used in some experiments was 70 ml 0.1 M-citric acid and 30 ml 0.2 M-disodium hydrogen phosphate, the vehicle being 5% methylcellulose.

RESULTS

Fertile couple

The immediate effect of the arrival of semen in the vagina was a change of

PLATE 1

Photographs showing pH-pill and radio-receiver.

(Facing p. 70)

vaginal pH from 4.3 to 7.2 in 8 sec (Text-fig. 1). Depletion of seminal volume (by four ejaculations within 48 hr) to 1.5 ml resulted in a change of vaginal pH, at intercourse, from 3.8 to 5.8 (Text-fig. 2). The effect of coitus and female

TEXT-FIG. 1. Effect of normal semen on vaginal pH during and after human coitus. E = ejaculation.

TEXT-FIG. 2. Effect of low seminal volume (due to repeated ejaculation in a fertile subject) on vaginal pH during and after human coitus. Note smaller and slower change in vaginal pH. E = ejaculation.

orgasm in the absence of semen (the male using a condom) was that no change in vaginal pH occurred (Text-fig. 3).

The use of a pH 3.6 buffer solution intravaginally during intercourse resulted in no change in vaginal pH during the first 2 min *post coitum* (Text-fig. 4) but after 2 hr, the vaginal pH was 5.4. In this experiment, three postcoital tests for

TEXT-FIG. 3. Effect of female orgasm on vaginal pH in the absence of semen. Note absence of change in vaginal pH despite sexual excitement and orgasm. O = orgasm.

TEXT-FIG. 4. Effect of pH 3-6 buffer introduced into vagina before coitus in a fertile couple. Note very little change in vaginal pH during and after coitus. E = ejaculation.

TEXT-FIG. 5. Effect of poor seminal specimen (in subject of low fertility and with ejaculate of low volume and sperm count) on vaginal pH during and after human coitus. Note smaller and slower change in vaginal pH. E = ejaculation.

sperm motility, taken after 3, 30 and 90 min respectively, showed no motile spermatozoa present.

Low male fertility

The effect of the arrival of semen in the vagina was a change of vaginal pH from 3.5 to 5.5 in 15 sec, with a rise to pH 5.8 after 3 min (Text-fig. 5). The vaginal pH remained at 5.8 for the next hour.

DISCUSSION

The studies of Muschat (1926) indicated that the motility of human spermatozoa ceased at a pH of less than 6 or more than 10. Shedlovsky *et al.* (1942) conducted titrations of human seminal fluid with acids and alkalis. Their excellent data show that certain acids, such as acetic and monochloroacetic, were most effective, inhibiting sperm motility in less than 30 sec if the pH was less than 4.7. They also remarked on the superiority of the spermicidal properties of well buffered tartrate and lactate solutions over solutions of the corresponding acids alone.

Basic studies on the biological characteristics of the normal vagina (Oberst & Plass, 1936; Rakoff, Feo & Goldstein, 1944), the composition and physiology of semen (White & Macleod, 1963; Raboch & Skachova, 1965) and the biochemistry of semen (Mann, 1964) have added greatly to our knowledge of this area of reproductive physiology, whilst Lang (1955) and Masters & Johnson (1966) have reviewed the particular topic of vaginal acidity. The latter authors provide a useful summary of experiments *in vitro*, but their own experiments *in vivo* on the effect of seminal fluid on vaginal pH deserve some criticism. It is hard to imagine how they managed to take the first postcoital pH test only 9 sec after ejaculation, when it is recalled that they were using glass electrodes for intermittent pH measurement. Furthermore, the term 'lethal factor' is frequently used without any elucidation of the nature of this factor.

Our own experiments have been hampered by the difficulty in obtaining experimental subjects for this sort of research. The rapid change of vaginal pH noted in the fertile couple indicates the powerful buffering capacity of normal seminal fluid, and our results resemble those of Masters & Johnson (1966). Our findings suggest that the vagina is not normally the hostile environment hitherto imagined. The failure of the stimulus of sexual excitement and its concomitant vaginal lubrication to change the vaginal pH is also noteworthy, and we question the nature of the 'sweating' described by Masters & Johnson (1961), since one would imagine this to be a transudate with a pH similar to that of plasma (around pH 7).

Repeated ejaculation is known to lower seminal volume and, in our experiments, low volume was equated with poor buffering power. A coexistent low sperm count could render a seminal specimen vulnerable to vaginal acidity. This is corroborated to some extent, notwithstanding cervical factors, by the success of AIH in our hitherto infertile couple.

By altering the chemistry of the vaginal secretion with the introduction of 10 ml buffer, pH 3.6, we were able to counteract the buffering power of normal

seminal fluid to such an extent that there was little change in vaginal pH after ejaculation. The telemetering device was left *in situ* for 2 hr but the maximal change was to pH 5.4. This suggests a possible field of investigation for a chemical contraceptive, since we have a scientific understanding of its mode of action. Such a buffer might affect the cervical mucus, which has a slightly alkaline pH, and might adversely affect sperm transport (see Odeblad, 1962, 1971; Davajan, Nakamura & Kharma, 1970). On the other hand, if some spermatozoa were sucked into the uterus during female orgasm (Fox & Fox, 1967; Fox *et al.*, 1970), they might escape the effects of the spermicide, and live spermatozoa could still be in the uterus in the presence of a negative postcoital test.

The use of a pH 7.4 buffer could be considered in certain cases of infertility.

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