Elemental composition of fluid in the human Fallopian tube

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Summary. Relatively undisturbed samples of human oviduct fluid were obtained by aspiration into a Silastic catheter inserted through the fimbriated end of the oviduct during surgical laparotomy. The concentrations of Na, Cl, K, Ca, Mg, S and P were determined in picolitre aliquots of this fluid using X-ray spectrometry by electron probe excitation. Human tubal fluid has a unique elemental composition characterized by high concentrations of K and Cl, but low concentrations of Ca, relative to the range of normal human serum values. Na and Mg concentrations in oviduct fluid are similar to serum levels.

Introduction

The oviduct provides the milieu for several critically important reproductive events, including transport of ova and spermatozoa, conditioning of the gametes, fertilization, and preimplantation embryonic development. Extensive work on the composition of oviduct fluid in a number of species has involved the use of double-ligature or cannulation techniques, and collection of fluid for long periods (for review, see Johnson & Foley, 1974). Up to the present, only two chemical analyses of human tubal fluid have been reported (Lippes, Enders, Pragay & Bartholomew, 1972; David, Serr & Czernobilsky, 1973). Both studies indicated that human oviduct fluid contains higher concentrations of chloride and potassium than does human serum. Roblero, Biggers & Lechene (1976) and Borland, Hazra, Biggers & Lechene (1977) have reported techniques for obtaining relatively undisturbed samples of oviduct fluid from the mouse and using electron probe excitation to analyse simultaneously in each sample seven different elements. Modifications of these techniques have now been used to analyse human tubal fluid from patients undergoing laparotomy.

Materials and Methods

Patients undergoing hysterectomy and bilateral salpingoophorectomy for menometrorrhagia provided the tubal fluid for this study (Table 1). The patients varied in age from 30 to 48 years and were premenopausal, except for patient R.M., who was perimenopausal. The patients were in various stages of their menstrual cycles, as estimated by the number of days since their last menstrual cycle and the endometrial histology. Histological sections of the oviducts indicated that no gross pathological processes disturbed normal oviduct morphology. Informed consent was obtained before surgery. After the abdomen was opened and just before the start of the hysterectomy, a Silastic (Dow Corning, Midland, Michigan) catheter containing sterile mineral

oil was then threaded down the fimbriated end of each Fallopian tube to a depth of 2.5–5.0 cm. A silk ligature was then placed around the oviduct and catheter near the fimbriated end to provide a tight seal. A 10 ml syringe with a blunt needle was attached to the catheter and negative pressure was exerted for 1 min. The catheter was then carefully withdrawn and its contents expelled into a Petri dish of mineral oil. Care was required to avoid contamination of tubal fluid with blood.

Table 1. Historical information on patients providing oviduct fluid for the present study

Name	Age (years)	Time from last menstrual period	Obstetrical history*	Endometrial histology	Oviduct histology	Post-operative diagnosis	Comments
E.H.	42	22 days	G5P3A2	—	No pathology	Uterine leiomyomata	—
R.M.	48	1 year	G3P1A2	Inactive endometrium	No pathology	Uterine leiomyomata	Patient perimenopausal
G.K.	30	22 days	G2P0	—	Mild chronic salpingitis	Chronic cervicitis with dysplasia	—
P.T.	32	16 days	G2P1A1	Early secretory changes	No pathology	Haemorrhagic corpus luteum cyst	—
M.O.	43	22 days	G4P4	Proliferative endometrium	No pathology	Uterine leiomyomata	On birth control pills
L.S.	43	—	G4P2A2	Mid-proliferative endometrium	Mild chronic salpingitis	Uterine leiomyomata	Menometrorrhagia for 3 years
S.L.	36	26 days	G0P0	Late secretory endometrium	Hydatids of Morgagni	Uterine adenomyosis and leiomyomata	—

* G = gravidity; P = parity; A = abortion.

An aliquot of each sample was drawn into a siliconized oil-filled micropuncture pipette. Additional mineral oil was taken into the pipette and the tip sealed by heat without disturbance to the sample. The pipette was then centrifuged for 15 min at 1470 g in a model CL International Clinical Centrifuge to separate any cells from the light yellow supernatant fluid. Samples with any blood contamination were not included in the study.

Sample preparation and electron probe microanalysis were by the techniques described by Lechene (1974), Lechene & Warner (1977) and Borland *et al.* (1977). The samples were first diluted 1:1 or 1:2 with distilled water. The samples and a series of standard solutions were placed on the surface of a beryllium support covered with mineral oil with calibrated volumetric pipettes (35–80 pl). The oil on the beryllium block was removed with an *m*-xylene wash and the sample on the block was freeze-dried under vacuum. The analyses were performed on an automated Cameca MS/46 microprobe. X-ray emissions from Na and Mg were analysed using potassium acid phthalate diffracting crystals; P, Cl, K and Ca required the use of pentaerythritol diffracting crystals. The concentrations of the elements in the unknown samples were determined with respect to the counts obtained from identical volumes of 5 standard solutions each of which contained known amounts of the 7 elements being studied. The electron probe measures the total content of all 7 elements in each sample and therefore the concentrations of Ca and Mg included the bound and unbound forms of these elements, and those of S and P represented the organic and inorganic forms. The electron probe has been shown to analyse reliably elements in fluid volumes as small as 10 pl provided the elemental concentrations are greater than 0.3 mM (Lechene & Warner, 1977).

Preoperative serum electrolyte concentrations were obtained from the chemistry laboratory of the Peter Bent Brigham Hospital, Boston, where the surgery was performed. Serum Na and K

were analysed by flame photometry, whereas serum Cl and Ca were analysed by titration and fluorometry, respectively. The ranges of normal serum electrolyte concentrations at the Peter Bent Brigham Hospital are shown in Table 3. Surgical specimens were examined by the hospital pathology department. The endometrial and tubal histologies and post-operative diagnoses are shown in Table 1.

Results and Discussion

The mean concentrations of Na, Cl, K, Ca, Mg, S and P in human tubal fluids from seven patients are shown in Table 2. The ionic composition of the fluid was characterized by high concentrations of K and Cl, but low concentrations of Ca, relative to corresponding serum levels.

Table 2. Concentration (mM) of Na, Cl, K, Ca, Mg, S and P in human oviduct fluid and human serum

Name	Fluid	Na	Cl	K	Ca	Mg	S	P
E.H.	Tubal	127.4	131.4	15.6	1.66	0.34	5.50	5.84
	Serum	145	111	3.9	2.62	—	—	—
R.M.	Tubal	104.2	122.2	15.3	0.85	1.32	18.44	7.30
G.K.	Tubal	140.7	161.7	27.2	0.15	1.71	5.73	9.54
	Serum	142	—	4.3	—	—	—	—
P.T.	Tubal	128.4	131.4	21.5	0.72	2.64	13.92	8.73
M.O.	Tubal	144.7	143.1	29.7	1.94	1.24	10.08	9.08
	Serum	131	95	4.1	—	—	—	—
L.S.	Tubal	134.4	124.3	15.4	1.67	1.29	16.06	9.28
	Serum	140	105	4.9	—	—	—	—
S.L.	Tubal	135.0	107.5	23.5	0.95	1.37	16.35	11.07
	Serum	145	113	3.8	2.52	—	—	—

The mean concentrations of the 7 elements in the oviduct fluids of our study are compared to previous elemental analyses of human tubal fluid (Table 3). Lippes *et al.* (1972) and David *et al.* (1973) also reported that K and Cl concentrations in oviduct fluid are consistently higher than in serum. The former investigators also noted that Ca concentrations in oviduct fluid are at the lower end of the normal range of the corresponding serum levels. The results of our own study show similar trends, but also indicate much higher concentrations of K in human oviduct fluid than previously reported. Human tubal fluid contains 4–5-fold higher concentrations of K than does human serum. The Ca concentration in oviduct fluid is less than half the serum Ca levels (Table 3), perhaps reflecting lower concentrations of protein in tubal fluid than in serum (David *et al.*, 1973) which could maintain Ca in a protein-bound form. The Mg concentration was not

Table 3. Mean ($\pm$ s.e.m.) concentrations of various elements in the fluid of human oviducts

Element	Hospital normal ranges for human serum	Tubal fluid (mM)				
		Borland <i>et al.</i> (1979) (N = 7)	Lippes <i>et al.</i> (1972) (N = 16)		David <i>et al.</i> (1973)	
			Pre-ovulatory	Post-ovulatory	Pre-ovulatory (N = 13)	Post-ovulatory (N = 11)
Na	139–147	130 $\pm$ 5	140 $\pm$ 3	139 $\pm$ 2	142 $\pm$ 4	148 $\pm$ 5
Cl	102–113	132 $\pm$ 6	119 $\pm$ 4	117 $\pm$ 3	127 $\pm$ 20	112 $\pm$ 11
K	3.6–5.0	21.2 $\pm$ 0.24	9.9 $\pm$ 1.8	7.7 $\pm$ 0.9	6.7 $\pm$ 1.3	6.7 $\pm$ 0.5
Ca	2.27–2.72	1.13 $\pm$ 0.24	1.89 $\pm$ 0.52	2.37 $\pm$ 0.27	—	—
Mg	0.55–1.57	1.42 $\pm$ 0.26	0.53–0.69	—	—	—
S	—	12.3 $\pm$ 1.9	—	—	—	—
P	—	8.69 $\pm$ 0.64	—	—	—	—

significantly different from the normal range of serum Mg levels. The reason for the discrepancy in K concentrations in Table 3 is not known, but may be related to differences in patient selection and fluid sampling techniques. There is no reason to suspect artefactually high K measurements because of the use of electron probe microanalysis. In our hands, measurements of K concentrations in biological fluids with the electron probe are identical to results with flame photometry.

The present values for human oviduct fluid are similar to those obtained for fluid from the isthmic and ampullary regions of the mouse oviduct under highly controlled laboratory conditions; i.e. high concentrations of K and Cl, but low concentrations of Ca (Roblero *et al.*, 1976; Borland *et al.*, 1977). The importance of this ionic composition for fertilization and preimplantation embryonic development in women and mice is not yet known. The human embryo normally enters the uterus at the 8- or 16-cell stage. Human oocytes that have been fertilized *in vitro* cleave regularly, albeit more slowly than *in vivo*, and eventually form blastocysts in culture medium that is ionically dissimilar to human tubal fluid (Stephoe & Edwards, 1976, 1978). Further studies are needed to determine the importance of the ionic composition of the oviduct fluid for normal human preimplantation development.

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