Ciliated fibroblasts and smooth muscle cells in the rat uterus

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Summary. Ciliation in endometrial fibroblasts and myometrial muscle cells of the rat was examined by transmission electron microscopy. Quantification of the number of ciliated cells during the estrus cycle did not show any firm relationship between cilation and ovarian hormonal activity. In the case of most cilia, there is a spatial relationship between their basal centrioles and the Golgi complex, so that a Golgi-cilium complex is created. A possible role of ciliation in uterine fibroblasts and smooth muscle cells is discussed.
Key words. Uterus; fibroblasts; smooth muscle cells; cilia; Golgi-cilium complex; electron microscopy; rat.

Since Sorokin's[1] description of ciliated fibroblasts and smooth muscle cells (SMC), primary (single) cilia may be considered a common feature of different cell types[2-7] including endometrial fibroblasts[8-10] and myometrial SMC[4,11]. However, the simultaneous presence of ciliated fibroblasts and SMC has not been studied in the uterus, nor has the relationship between cilia and the Golgi complex[5,6] been examined. The present study 1) extends the general data on ciliation in rat endometrial fibroblasts and myometrial SMC, 2) quantifies the numbers of ciliated fibroblasts and SMC during the estrus cycle, and 3) documents the existence of the Golgi-cilium complex in these particular cells.

Materials and methods

Wistar rats (n = 30) were used and specimens were taken from the uteri (midportion of the horn) and processed for transmission electron microscopy using the routine glutaraldehyde-OsO_4 method. Ultrathin sections (uranyl acetate, lead citrate) were examined with a JEM 7A or EM 109 Turbo (Opton) electron microscope. Vaginal smears were taken from the rats to establish the presence of a regular, 4-day estrus cycle and its various stages; 3 rats were studied in each of the 4 stages. Uteri from newborn, 5-, 10-, 20-, 60-day-old and menopausal rats (n = 3 at each age) were also examined. To determine the number of ciliated cells as a percentage of the total cells, more than 100 fibroblasts (in endometrium) and 100 SMC (in myometrium) were counted during the observation of ultrathin sections from the uterus at each stage of the estrus cycle.

Results and discussion

A total of 156 ciliary profiles were recorded and analyzed (124 in fibroblasts; 32 in SMC) during the estrus cycle; in addition, more than 100 ciliated fibroblasts and SMC were also analyzed. Cilia occurred more commonly in fibroblasts than in SMC. Their presence varied during the estrus cycle (table). It is, however, difficult to evaluate precisely the relationship, if any, between ovarian hormonal activity and ciliation, either in fibroblasts[10] or in the SMC. The estradiol level starts to rise during diestrus and reaches its highest level in proestrus, and its lowest in metestrus[12]. It therefore appears that there is a somewhat positive correlation between estradiol action and ciliation, at least in the fibroblasts examined here (see 8 for opposite results). However, in immature rats, ciliated fibroblasts and SMC were also frequently encountered, so a factor(s) other than hormones may be involved (see below).

In cross sections, the cilia usually showed a 9 + 0 axonemal pattern. In other planes of sectioning, most cilia in fibroblasts and SMC revealed a spatial relationship be-

Percentage of ciliated cells during the estrus cycle in the uterus of rats (n = 3 at each of the stages)

Stages of the estrus cycle	% of ciliated cells	
	Fibroblasts*	Smooth muscle cells**
Proestrus	4.26 ± 1.67	2.75 ± 1.47
Estrus	7.32 ± 2.52	1.11 ± 0.97
Metestrus	3.70 ± 1.68	1.51 ± 1.33
Diestrus	10.20 ± 2.63	2.05 ± 1.32

Each value represents the mean ± SD. *All values are compared with each other; with two exceptions, metestrus compared with proestrus and diestrus compared with estrus, all others show $p < 0.05$ using Student's t-test. **No significance, when values treated like those for fibroblasts.

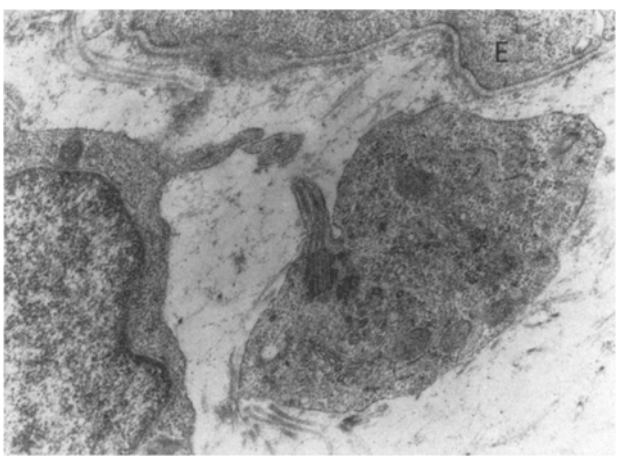

Figure 1. Ciliated fibroblast in the uterine endometrium of a 10-day-old rat. The ciliary shaft appears projecting above the cell surface and forward to the epithelial layer (E). The basal centriole is associated with the Golgi complex. ×12,000.

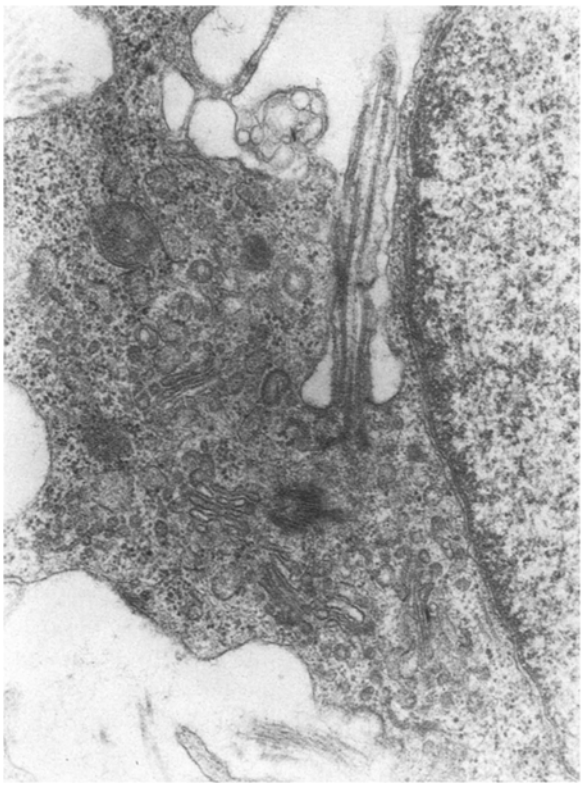

Figure 2. Ciliated fibroblast in the uterine endometrium of a 20-day-old rat. The ciliary shaft appears with approximately one-third of its whole length projecting above the cell surface. A remnant of the basal centriole, a part of the proximal centriole, and the associated trans-Golgi area can also be seen. ×15,000.

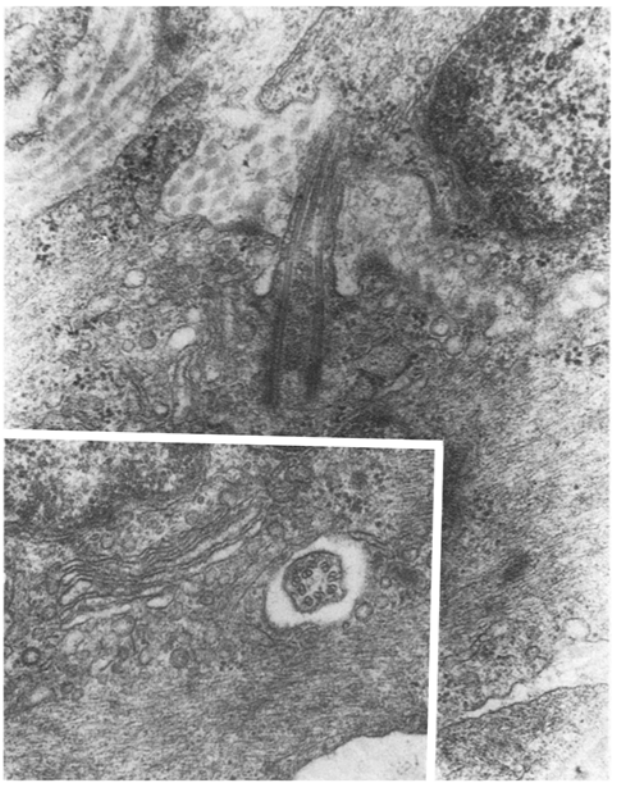

Figure 3. Ciliated smooth muscle cells in uterine myometrium in diestrus. The tip of the ciliary shaft seems to be approaching the surface of an adjacent muscle cell. A part of the Golgi complex is placed near the basal centriole. In the inset: cross-sectioned cilium showing 9 + 0 axonemal organization of microtubules, and Golgi complex located near (?) cilium ×20,000.

tween their basal centrioles and the Golgi complex (figs 1–3), a trans-Golgi-cilium complex being the most common variation[5,6]. Considering the well-known trans-Golgi-centrosome relationship[13,14], the present finding of the Golgi-cilium complex appears to be a logical observation, although the functional aspects of such a complex have been ignored except by Poole et al.[5] and Tenkova and Chaldakov[6]. Rootlets that usually link the basal centriole to the Golgi complex[5,6,10] were found only once, in a fibroblast.

The possible function of the primary cilium is still a subject for hypothesis[1–11]. The widespread occurrence of similar cilia in sensory, nervous and endocrine tissue raises the possibility that they may have some sensory role[5,15]. If so, the Golgi-cilium complex, and the ciliation in the uterus in general would allow a local response to mechanical, chemical and osmotic changes taking place in the extracellular matrix in both endo- and myometrium, as previously proposed for other types of connective tissue[5]. We have also found ciliation in pericytes, vascular endothelial cells, macrophages and Schwann cells (data not shown). Thus, it seems possible that all the uterine ciliated cells may create a 'ciliary network', operating as a multifunctional, sensory apparatus of the rat uterus, which might possibly be controlled by cyclic AMP[13,14].

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