Imaging in Pediatric and Adolescent Gynecology

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Sonography is a versatile diagnostic imaging modality which uses acoustical energy. In the pediatric patient, it can be used in several areas of the body, particularly within the abdomen and pelvis.

Over the last several years, the use of sonography for the evaluation of pediatric disorders has become more widespread for several reasons. These include the non-ionizing character of sonography relative to the radiographic techniques and the enhanced soft tissue detail now afforded by most real-time ultrasound scanners. The increased use and availability of real-time scanners has also contributed to more extensive use of sonography. Since children have very little perivisceral fat, they are almost ideal subjects for ultrasound scanning because high-frequency transducers which afford the best possible resolution can be used. The lack of irradiation allows repeat examinations to be performed without fear of untoward bioeffects due to radiation.

The role of sonography in the evaluation of pediatric gynecologic disorders will no doubt continue to expand, particularly as more pediatricians, gynecologists and radiologists become more familiar with its applications in pediatric gynecology.

The Infant and Adolescent Uterus

The uterus grows progressively during fetal life. After birth, uterine volume is relatively higher, longer and thicker than the prepubertal uterus and shows endometrial and myometrial characteristics very similar to those of adults.

After the first weeks, uterus size regresses, probably because of the withdrawal of maternal hormone stimulation. During childhood the uterus shows no
changes in size and shape until the age of 7 years (fig. 1) [1]. From this age onward, uterine volume increases progressively at a slow rate before the appearance of secondary sexual characteristics. A sharp acceleration is seen during puberty, which has a good correlation with Tanner stages (fig. 2), age, weight, height and estradiol levels, and the most dramatic changes are seen between stages 3 and 4 of breast development.
After menarche, the uterus continues to grow, even after the almost complete development of the secondary sexual characteristics [2]. Menarche is a critical step toward the development of the whole reproductive system, especially of the uterus, which assumes a new function. After menarche, uterine growth rate slows and gradually tends to take on the adult size and structure. However, normal adult values are not attained even by the sixth gynecologic year (fig. 3), which shows that full development of this reproductive organ takes even more time, although adult morphology and corpus/cervix ratio are already achieved by menarche.

Among the reproductive hormones, estradiol seems to be the main agent for uterine growth. Other reproductive parameters, such as the frequency of menstrual bleeding and that of ovulation and progesterone levels, do not appear to be related to uterine size and growth rate.

Height and weight correlate with uterine volume before menarche but not afterward, since at this age they have nearly exhausted the developmental changes and vary independently of growth factors. The adrenal steroids dehydroepiandrosterone and dehydroepiandrosterone sulfate, which are reliable

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**Fig. 3.** Mean values (± SD) of uterine volume grouped according to gynecologic (a) and chronological years (b) in adolescents. Sexually mature controls (C) are reported. Number of subjects is reported in each column. *p < 0.01; **p < 0.001, with respect to control uterine volume. (c) Mean ovarian/uterine ratio in adolescent girls during gynecologic years and sexual mature controls (C) [from 2].
indexes of biologic maturation, continue to increase during adolescence and, interestingly, they correlate with uterine development.

The finding of a still small uterus during adolescence may have reproductive implications. The lack of complete genital tract maturity might partly account for problems such as preterm labor, preeclampsia, and small-for-gestational age infants; these problems are not uncommon in adolescence.

The ovarian/uterine ratio decreases with increasing gynecologic age (fig. 3). The mean value at the first gynecologic year is very similar to that found in the polycystic ovary syndrome, probably because, unlike the uterus, the ovaries seem to have already reached complete growth at menarche. Furthermore, their volume often exceeds the adult value and needs a reduction in size to reach the final maturational step.

**Ovarian Development during Puberty and Adolescence**

Before the increasingly common use of ultrasound evaluation of the ovaries, anatomical and histological descriptions gave us a dynamic image of the developing ovary documenting that during childhood the ovary is never at rest and follicles grow and degenerate continuously. Peters et al. [3] identified three steps of ovarian growth: the quiescent ovary, with small resting follicles and occasional preantral follicles; the ovary in early growth, with small follicles, preantral follicles and occasional antral follicles not larger than 0.5 mm; and the actively growing ovary that is more and more frequent after the age of 6 when antral follicles, which are usually well distended, become increasingly numerous and large. These follicles have been called ‘cystic’ but they are normal follicles, some of them healthy, others in degeneration.

The ovarian size increases throughout childhood in relation to a gradual increase in the number as well as in the size of the antral follicles and a progressive increase of the stroma derived from follicle atresia. Besides multiple follicle growth and atresia, partial luteinization of the theca interna and fibrosis of the cortex are common features in the normal process of follicular development throughout infancy and childhood, so that early pubertal ovaries have been described that are indistinguishable from those of the polycystic ovary syndrome.

The advent of ultrasound has enabled clinicians to easily examine ovaries of a large number of girls and, moreover, to follow their development (fig. 4). Antral follicles or microcysts not exceeding 9 mm, as defined by ultrasound, start to increase around the age of 9 with the appearance of fluid areas $>9$ mm after the age of 11 [1].
In the years immediately before menarche, the cystic structure becomes prevalent. The increase in cystic structure coincides with the beginning of the gonadotropin rise which seems to play a central role in the last stages of follicular development. At this age gonadotropin secretion changes its quality, enhancing its pulsatile characteristics, both episodic and circadian, and sending a faster and more fluctuating signal to the ovaries which accelerate the turnover of follicular development. The follicles increase in size and steroid production.

Figure 5 shows an early pubertal nocturnal rise of LH, with levels remaining very low during the day. However, only a few nocturnal pulses are sufficient to promote the progression of some follicles in the still small ovaries. A higher number of LH pulses can occasionally be present also during the day in premenarcheal girls at mid and late puberty when ovaries show a higher volume and number of follicles compared to the previous stage (fig. 5). In fact there is a positive correlation between Tanner stages and ovarian volume (fig. 6).

The functional result of these integrated movements is the increase in steroidogenesis. Indeed, there is a positive correlation between ovarian volume, estradiol ($E_2$) and testosterone (T). In the same subject we can find greater or lesser follicular activity at different times in this period of life. Therefore, before menarche, multifollicular ovaries mean more and more activated ovaries but sometimes overactivated ovaries.

Just before menarche, puberty is characterized by the interaction of two evolving systems: the increasing gonadotropins and the actively growing ovary. For correct reproductive development, the two systems should interact in the most appropriate way and time and after puberty the dominant follicle growth should take over, with a decrease in the number of developing follicles.

Any derangement, i.e., an abnormal gonadotropin signal or an excessively prolonged process, may potentially lead to pathology. According to the number of developing follicles the sonographic appearance of the ovaries may be

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**Fig. 4.** Ultrasound ovarian appearance before puberty (a) and after puberty onset (b) [from 1].
Fig. 5. Gonadotropin profiles and related sonographic ovarian appearance at (a) early, (b) mid and (c) late puberty.
homogeneous, when fewer than four cystic areas are present, and multifollicular, when four or more fluid areas are imaged by ultrasound. It must be stressed, however, that this is an oversimplification since a wide spectrum of images, with a variable number of developing follicles, may be found.

Figure 7 shows that girls with regular cycles have normal ovarian volume and a homogeneous appearance. Girls with irregular cycles, however, have a mean volume significantly higher than those of regular ovulatory adolescents and those of adults. The postpubertal developing ovary is then mostly enlarged and multifollicular [4]. What is the differentiating element with polycystic ovaries (PCO)? Many authors have tried to classify the ‘jungle’ of ovaries with ‘multiple echo-free areas’ or ‘fluid images’, according to the number, size and distribution of cystic areas, the amount of stroma, the ovarian volume, the uterine-ovarian ratio, and the morphofunctional responses to induction of ovulation [5–7].

An appropriate classification might be the one outlined in table 1 where multifollicular ovaries have more than 5 cystic areas spread throughout the stroma (fig. 8) and polycystic ovaries have more than 10 cysts arrayed peripherically (fig. 9).

Adolescent ovarian development passes through different sonographic stages to lead to the normal adult ovary. This evolution is driven by the increasing

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Fig. 6. Ovarian volume according to pubertal stage.
Table 1. Classification of ovaries

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<tr>
<th>Type of Ovaries</th>
<th>Description</th>
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<tr>
<td>Homogeneous ovaries</td>
<td>Normal or low volume</td>
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<td></td>
<td>Few cystic areas (&lt;4) not &gt;3–5 mm</td>
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<tr>
<td>Multifollicular ovaries</td>
<td>Normal or increased volume</td>
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<td>Several cystic areas (&gt;5) 5–10 mm large spread throughout the ovarian stroma</td>
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<tr>
<td>Polycystic ovaries</td>
<td>Normal or increased volume</td>
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<td>Many cystic areas (&gt;10) 3–8 mm in diameter arranged peripherally or located in the inner part of the ovary</td>
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<tr>
<td>Multifollicular or polycystic ovaries plus leading follicles</td>
<td>The same as above – one or two cystic areas &gt;13 mm</td>
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Fig. 7. Distribution of ovarian volume in girls with (a) regular and (b) irregular cycles [from 4].

The number and regularity of ovulations (fig. 10) [8]. The more ovulations, the lower the ovarian volume and the number of follicles.

The time necessary to ‘learn’ how to ovulate seems crucial for the development of a normal ovarian structure. There seems to exist a sort of temporal window in which the ovaries are still plastic and can undergo morphological changes. Outside of this framework, the ovary has great difficulty moving...
Fig. 8. Sonographic aspect of a multifollicular ovary.

Fig. 9. Sonographic aspect of a polycystic ovary.

Fig. 10. Ovarian volumes at various frequencies of ovulation. A = Anovulation [from 8].
Fig. 11. Longitudinal examination of the ovaries. Distribution of the subjects (n = 46) with normal ovarian volume during the first control (left) and outcome of the ovarian volume and morphology as found during last control (right). During the last control, 14 subjects (30%) showed ovarian volume exceeding the normal range; polycystic structure was the dominant feature. Continuous lines connect the subjects with normal ovarian volume during the first control and enlarged ovaries in the last control. Dashed lines indicate normal adult range of ovarian volume. ■ = Homogeneous ovary, first control, n = 26; last control, n = 15; ★ = Multifollicular ovary, first control, n = 13; last control, n = 11; ▲ = polycystic ovary, first control, n = 7; last control, n = 20 [from 9].

beyond the adolescent structure. Years of anovulation and particularly of increased LH secretion mark the ovary irreversibly, increasing the stroma and turning the multifollicular aspects into the polycystic structure.

The duration of anovulation is probably the key factor responsible for the onset of the persistence and worsening of the polycystic structure.

A prospective longitudinal study documented that in the years after the menarche, the ovarian volume changes from normal to enlarged in 30% of the adolescent population (fig. 11) [9]. The postmenarcheal period is frequently the starting point for the polycystic transformation of the ovaries [10–12]. By contrast, in some subjects with enlarged multifollicular and polycystic ovaries
Fig. 12. Longitudinal examination of the ovaries. Distribution of the subjects (n = 27) who showed the ovarian volume exceeding normal adult range during the first control (left) and outcome of the ovarian volume and morphology during the last control (right). Six (22%) subjects showed the ovarian volume within the normal range during the last control, but the inhomogeneous structure persisted. Continuous lines connect the subjects with ovaries exceeding normal adult volume during the first control and ovaries within normal range in the last control. Dashed lines indicate normal adult range of ovarian volume. ■ = Homogeneous ovary, first control, n = 0; last control, n = 2; ★ = multifollicular ovary, first control, n = 4; last control, n = 3; ▲ = polycystic ovary, first control, n = 23; last control, n = 22 [from 9].

(22%), ovarian volume can become normal (fig. 12). It is well known that multifollicular morphology of the ovaries may revert to normal when ovulation is achieved. On the other hand, the possibility of achieving a normal adult echographic image with a homogeneous structure of the ovaries during the postmenarcheal period was not observed for the polycystic ovaries. A shift from polycystic to multifollicular appearance was detected in 2 cases only; this is sufficient to confirm that the transition from one structure to the other may occur. A cross-selectional study [13] documented in 139 adolescents a relatively high frequency of ovarian cysts (12%). Most of them were simple
follicular cysts (fig. 13) and disappeared spontaneously. One cyst was a benign teratoma (fig. 14) and one was an endometrioma (fig. 15) and required surgical intervention. Another possible ovarian pathology is cystoadenoma (fig. 16).
These data suggest that serial ultrasound evaluations are indicated in adolescence to monitor the correct ovarian development and to prevent or early diagnose pathology.

**Fig. 15.** Endometrioma.

**Fig. 16.** Cystadenoma.
References


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