Chapter 1

Introduction

Initially this book was conceived as an ultrasound imaging reference volume for nurses and clinicians working in the field of assisted reproductive technology (ART), to illustrate the use of ultrasound in fertility clinics. To reach a wider audience, more information was added, as a reference guide for trainee sonographers, medics, general gynaecologists and midwives.

Concomitant with use of sonography as a diagnostic imaging tool, it is equally important that the sonographer/practitioner have an inquisitive mind, as well as good spatial ability to understand relationships among physical objects. This book is intended to provide operators with an overview of the process and give a foundation to guide their ultrasound assessment of each individual and unique patient.

Sonography uses sound waves to produce a greyscale image of a slice (cross-sectional image) of a selected organ or combination of anatomical structures. In real time the cross-sectional images change with the movement of the probe. Very slight moves will change the view of the area being examined. Image acquisition during an ultrasound examination requires a steady hand and a keen eye.

The objective of ultrasound during a cycle of assisted conception is to identify the anatomic structures within the female pelvis, identify the uterus and measure the endometrium, identify both ovaries, count and measure the follicles and recognise and image pathology, if present. The examination can be extended, to include the kidneys or the peritoneal cavity for fluid.

Women should have had a comprehensive gynaecological scan prior to commencing assisted fertility treatment, ART; however, it is necessary to document any pathology identified, as it may be new or undetected on previous scans.

Ultrasound in ART provides visual monitoring of the endometrium of the uterus and the number and size of the follicles in the ovaries during the first part of the menstrual cycle. This visual record and the blood tests provide for a more accurate management plan to be used, for individual patient needs, whether she is on a monitored or medicated cycle.

Transvaginal ultrasound enables good resolution of the tissues in most cases; however, it is operator dependent. Knowledge of the relevant anatomy, physiology, physics and instrumentation and using a systematic approach are required to produce and interpret the images.

Pathology and congenital anomalies may also be seen during the examination. Some examples are also included in this text.

Transabdominal ultrasound may be required in cases in which the ovaries are located high in the pelvis and access is limited using the transvaginal approach.

Assisted conception procedures are designed to increase the chance of pregnancy. The treatments vary and depend on the cause of infertility.

Blood tests show the amount of oestrogen in the blood (serum oestradiol levels). On day seven or eight transvaginal ultrasound is performed to see how many follicles are developing in each ovary. With rising oestrogen levels, a repeat scan two days later will show further growth or maturity. Depending on the patient's response to treatment a third scan may be required.

When the follicles have reached an appropriate size, a medication is administered to trigger oocyte maturation and oocyte retrieval is planned.

The Role of Ultrasound in Fertility Treatments

The ultrasound appearance of the ovaries, during ovarian stimulation, differs dramatically with the growth of multiple follicles, compared to the ovaries in a natural cycle. In a stimulated cycle, follicle-stimulating hormone (FSH, with or without the addition of luteinising hormone [LH]) is administered, to encourage the growth of small follicles, to a size at which the collection of a mature oocytes becomes possible.

During the stimulation, either a gonadotropin-releasing hormone (GnRH) agonist or a GnRH antagonist is administered to prevent ovulation prior to the time of oocyte retrieval. If ovulation was to occur prior to the time of oocyte retrieval, the oocytes would be lost into the pelvis and retrieval would be extremely difficult.

The Natural Cycle

Ultrasound is performed on day 11–14 (approx.) to check the thickness of the endometrium. (Figure 1.1) A single dominant follicle is usually present on one ovary and several smaller follicles in each ovary. (Figure 1.2) The number of small follicles present in the ovaries will depend on the woman's ovarian reserve.

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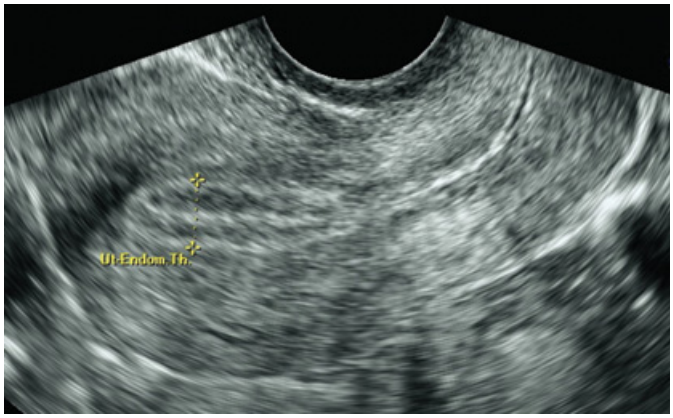

Figure 1.1 Endometrium measuring 10 mm, showing the tri-line appearance of the endometrium.

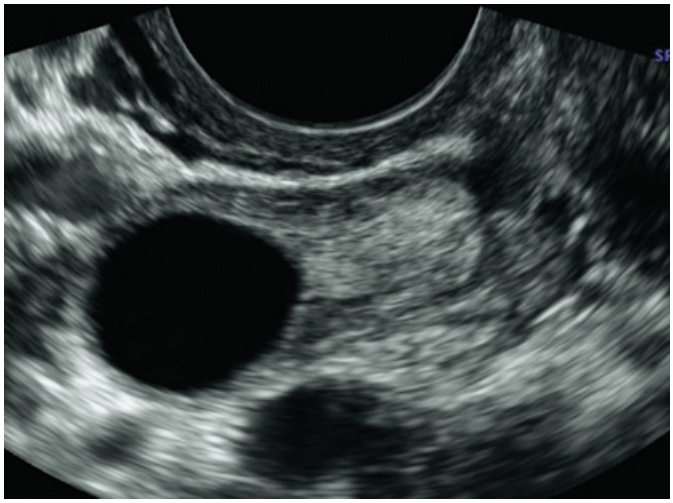

Figure 1.2 A single follicle seen in the natural cycle.

Ovulation Induction

Mild ovarian stimulation is conducted with medications such as clomiphene, letrozole or low-dose FSH to encourage the growth of one follicle. Ultrasound is used to check the number and size of follicles developing. If more than one follicle has developed, the cycle may be cancelled to avoid the potential of a multiple gestation.

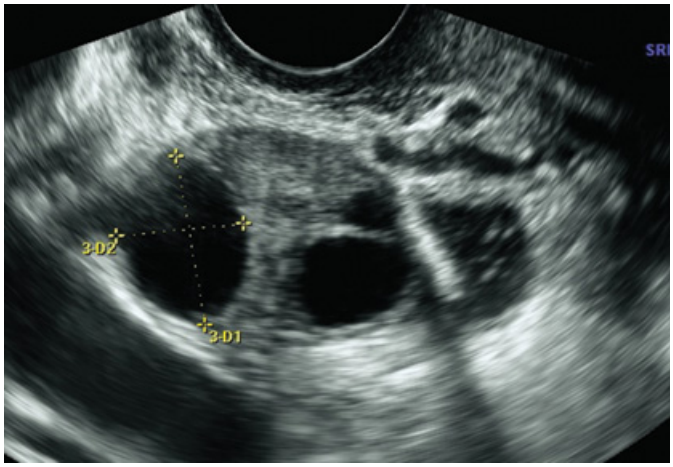

Figure 1.3 Right ovary with three follicles of various size seen in this one slice.

In Vitro Fertilisation Cycle

Ultrasound is used to check the number and size of the developing follicles within each ovary, during a stimulated cycle. Patients are monitored closely until the optimum number and size of developed follicles is reached.

With each scan, the endometrial lining of the uterus is assessed and measured in the mid to late proliferative phase. It grows under the influence of oestrogen during the ovary's follicular phase of the cycle.

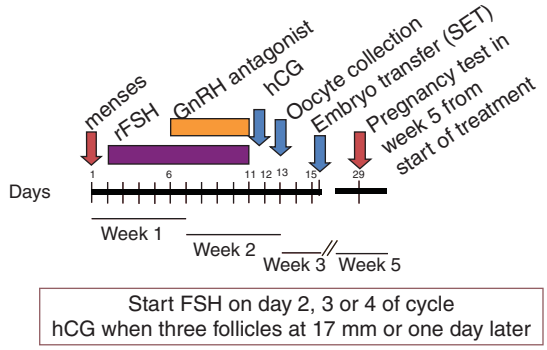

Figure 1.4 Standard antagonist protocol. Reproduced with permission of W Ledger

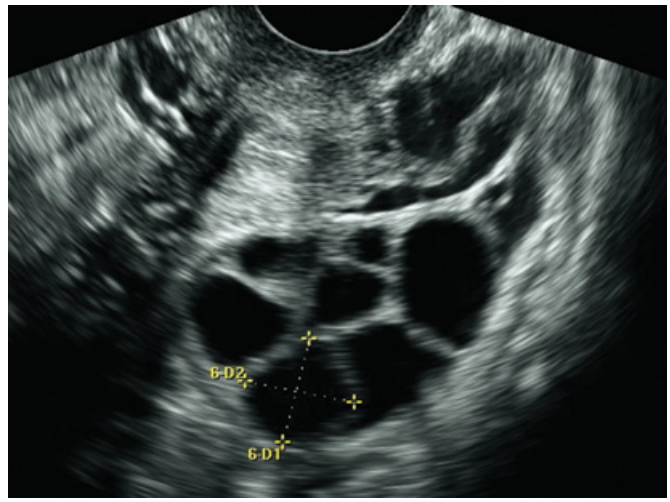

Figure 1.5 Multiple follicles in a stimulated in vitro fertilisation cycle.

Long Down-Regulation (Agonist)

The treatment cycle is a process of suppressing a woman's natural hormones before starting fertility medications.

Each woman should be independently evaluated to safely optimise egg quantity, without compromising quality. Long pituitary down-regulation protocols involve the administration of an agonist over four or more days before initiating ovarian stimulation.

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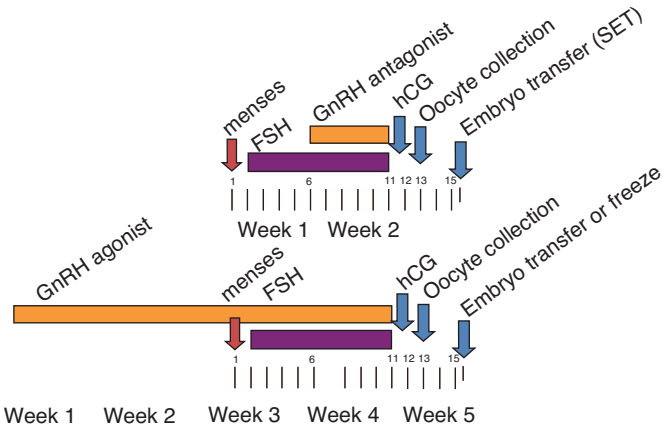

Figure 1.6 Agonist versus antagonist.
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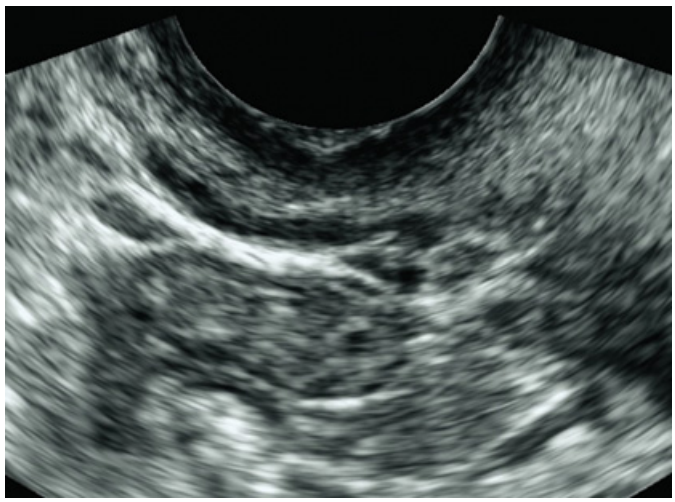

Figure 1.7 Agonist cycle before the start of fertility medications show small follicles in the ovary located between the uterus to the right of image, the pelvic wall to the left and bowel seen deep to the ovary.

Scan Prior to Embryo Transfer

The timing for thawed embryos to be transferred depends on tracking the ovarian cycle. Prior to the embryo transfer, ultrasound is used to determine the thickness of the endometrium and to assess each ovary, looking for a dominant follicle, in a natural cycle, and an absence of large follicles in a medicated cycle.

This scan, with the blood test results, is for the purpose of determining the optimal time to be planned for the fertilised ovum to be transferred to the uterine cavity. see Figures 1.1 and 1.8

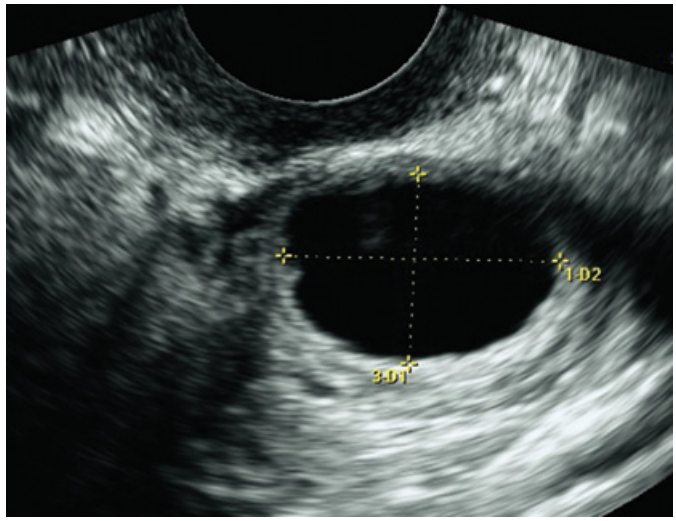

Figure 1.8 Dominant follicle measuring 20 mm.

Anatomy and Physiology of the Female Reproductive System

The uterus and the ovaries are located deep in the female pelvis, between the urinary bladder and the rectum. The uterus measures approximately 7–8 cm in length and is a pear-shaped structure with the Fallopian tubes extending bilaterally from the cornua, the upper lateral aspects of the uterus. The uterus consists of the cervix, isthmus, body and fundus. The muscle wall of the uterus is the myometrium and the inner lining of the body of the uterus is the endometrium.

The inner endometrial layer is the functional layer into which the embryo implants. It increases in thickness during the menstrual cycle and is shed during menstruation if conception does not occur. Figure 1.9

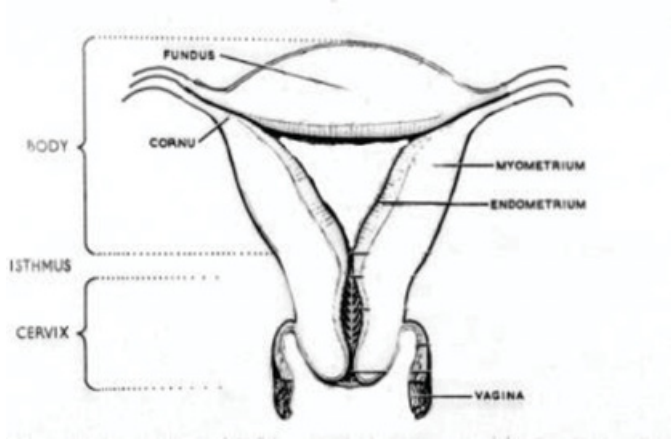

Figure 1.9 Coronal section of the uterus.

The parietal peritoneum is the lining of the abdominal cavity, which extends from the anterior wall into the pelvis, to cover the superior wall of the bladder and folds back on itself, at the level of the uterine isthmus to cover the anterior body of the uterus. Passing over the fundus, it extends over the posterior body of the uterus to the level of the cervix and folds upwards to cover the rectum, forming the recto-uterine pouch

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or pouch of Douglas (POD). Accumulated free fluid in the peritoneal cavity may be seen in the POD.

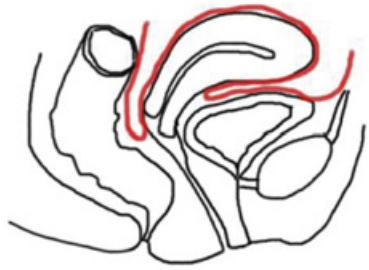

Figure 1.10 Folds of the peritoneum seen in median sagittal section of the female pelvis.

A double peritoneal fold forms the broad ligament of the uterus and extends laterally, from the uterus to the side walls and floor of the pelvis. The broad ligament encases the Fallopian tubes, within a small mesentery called the mesosalpinx. The ovarian and uterine blood vessels, lymphatics and nerves pass within the suspensory ligament of the ovary, which becomes continuous with the mesovarium of the broad ligament.

The uterine arteries arise on each side from the anterior branch of the iliac arteries. They pass anterior to the ureter to the uterus, in the cardinal ligament, through the inferior broad ligament and up along the lateral walls of the uterus to connect (anastomose) with the ovarian arteries.

The ovaries are located on the posterior aspect of the broad ligament, suspended by ovarian mesothelium. The ovaries are attached to the ligament by the utero-ovarian ligaments. Each ovary measures approximately 30 × 20 × 10 mm. The ovaries are not covered by peritoneum and the oocyte expelled at ovulation passes into the peritoneal cavity and is trapped by the fimbriae of the infundibulum of the uterine tube and carried into the ampulla, where it may be fertilised.

The cervix protrudes into the upper vagina, and the recess around the cervix is the vaginal fornix. The recess behind the cervix is called the posterior fornix. The smaller recesses anterior and laterally are the anterior and lateral fornices. The transvaginal probe is directed into this space to image the uterus and ovaries.

The uterine cavity is continuous with the cervical canal, which passes through the isthmus, the body of the uterus and laterally into each Fallopian tube. The distal fimbrial end of each fallopian tube opens into the peritoneal cavity and lies in close proximity to the ovary.

Uterine Position

The cervix is located centrally in the pelvis, being supported anteriorly by the pubo-cervical ligament, laterally by the transverse cervical or cardinal ligament and posteriorly by the uterosacral ligament.

Uterine position within the pelvis can vary from anteverted, where the fundus is anterior to the cervix, to retroverted, with the fundus located posterior to the cervix, also anteflexed and retroflexed.

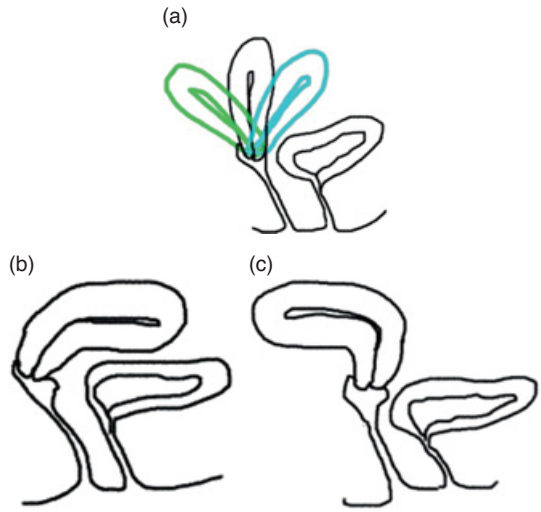

Figure 1.11 (a) The uterine position is described as anteverted (blue), retroverted (green), or in the long axis (black) by the position of the fundus being anterior, posterior or in line with the cervix. (b, c) The uterus seen in anteflexed and retroflexed position.

The Menstrual Cycle

The hormonal control of the menstrual cycle is complex. It is regulated by the hypothalamic–pituitary–ovarian axis. The hypothalamus releases GnRH in a pulsatile manner. This stimulates the anterior pituitary to release FSH and LH. FSH stimulates the growth of ovarian follicles. Around day 14 of a 28-day menstrual cycle, rising oestrogen levels trigger a surge of LH to be released from the anterior pituitary. The LH surge triggers the maturation of the oocyte contained in the dominant follicle. Approximately 36–38 hours after the LH surge, ovulation occurs.

Following ovulation, the theca granulosa cells of the follicle transform into lutein cells, and the follicle becomes known as the corpus luteum. If pregnancy does not occur, the corpus luteum ceases production of progesterone. The sudden drop in serum progesterone triggers menstruation.

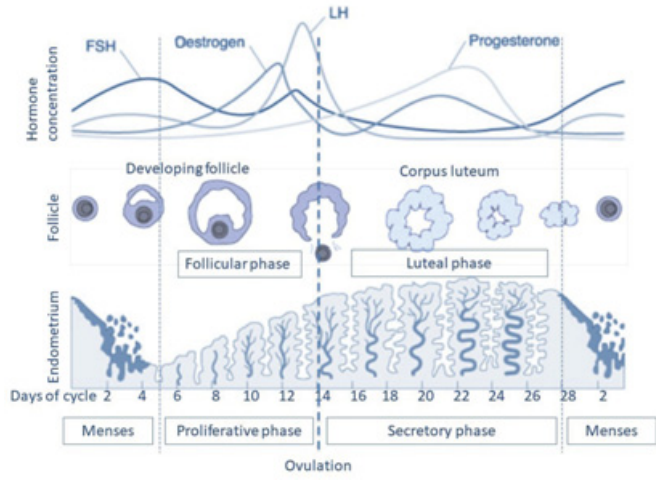

Figure 1.12 Menstrual cycle.
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Physiology of the Uterus

Throughout the menstrual cycle, the endometrium thickens and the change in appearance can be seen and measured using ultrasound. Measurements are taken through both layers from the basal layer to the opposite basal layer, reaching a maximum diameter of 14 mm during the secretory phase of the cycle.

The uterus is a dynamic organ, and with real-time ultrasound imaging contractions may be seen in midcycle. A slow wave moves along the endometrium from the internal os towards the fundus.

After menses the endometrium is seen as a thin line, which thickens during the proliferative phase of the cycle.

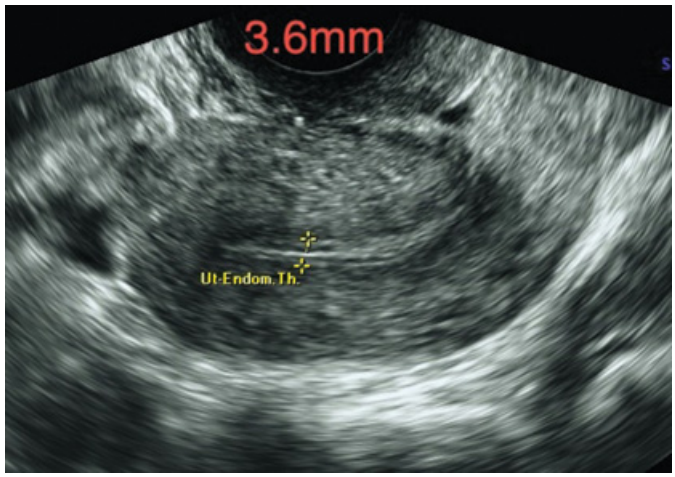

Figure 1.13 Endometrium is thin: day 5 of the cycle.

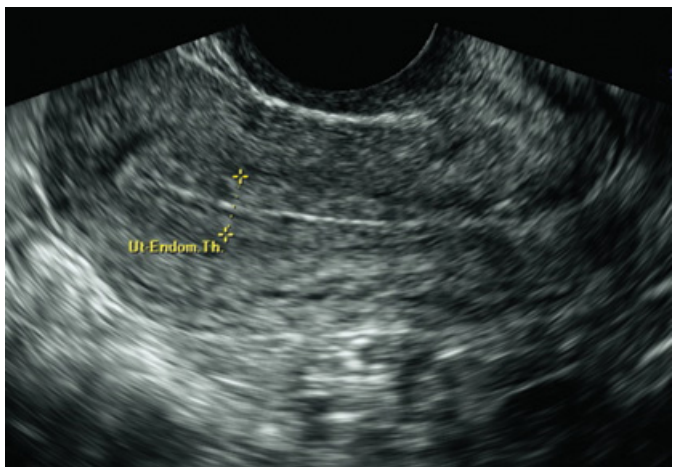

Figure 1.14 Endometrial thickness has increased to 6.8 mm but the basal layer is not echogenic.

By day 10 of the cycle the endometrium will be seen with the echogenic basal layer surrounding the endometrium with the uterine cavity in the centre, creating the tri-line appearance.

The endometrium measurement is taken, in the image of the long axis of the uterus, from the outer edge of the basal layer to the outer edge of the basal layer on the opposite side, at 90 degrees to the cavity echo. Optimal measurements in the late proliferative phase are 7–12 mm.

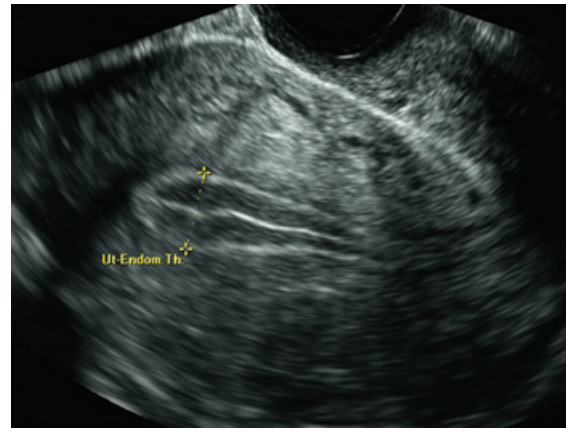

Figure 1.15 Endometrium with tri-line appearance caused by the echogenic basal layer surrounding the echogenic central cavity layer. These surfaces are at 90 degrees to the beam and act as specular reflectors.

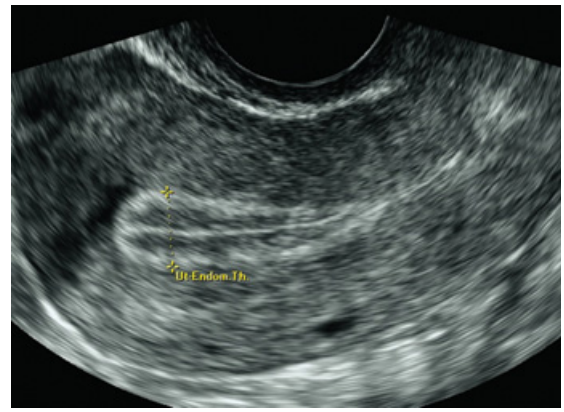

Figure 1.16 Tri-line pattern of the endometrium measuring 9 mm.

After ovulation, in the secretory phase of the cycle, the endometrium is seen on ultrasound as being echogenic, due to the many reflections from the surfaces of the more tortuous vessels. The maximum full thickness of the endometrium is 14 mm at days 19–23.

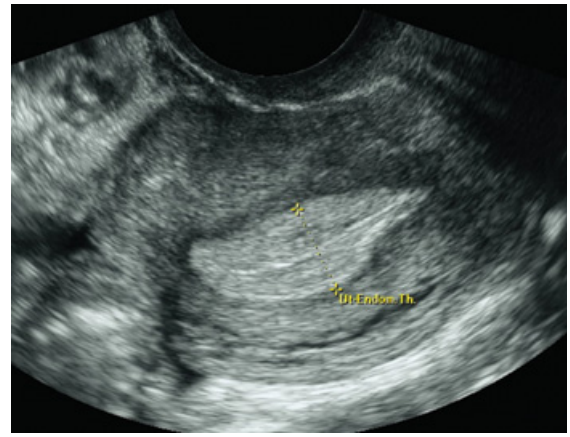

Figure 1.17 Ultrasound appearance of the endometrium in the secretory phase of the menstrual cycle. The increase in echogenicity is due to the increase in the number and tortuosity of the reflecting surfaces of vessels and glands within the endometrium.

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Physiology of the Ovaries

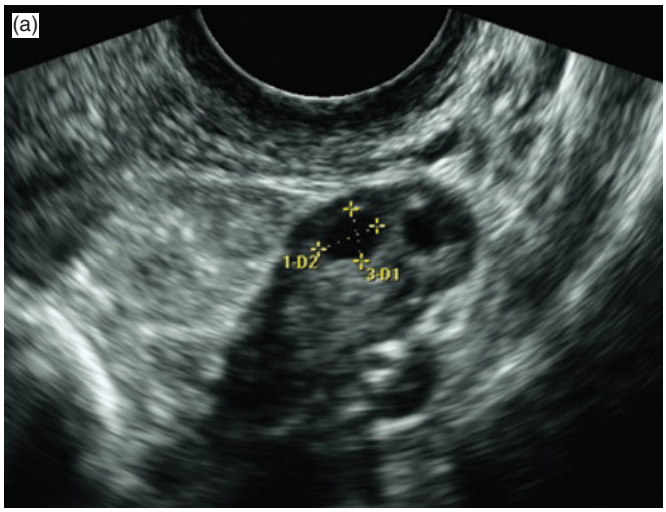
Changes within the ovaries occur during the menstrual cycle, with the growth of follicles, ovulation and the development of the corpus luteum after ovulation.

Follicles in the ovary can be visualised on ultrasound as fluid-filled structures, physiological cysts.

In women who do not have a reduced ovarian reserve, several small follicles can be seen in each ovary during the first half of the menstrual cycle (follicular phase). In women with a reduced ovarian reserve (most commonly older women), these small follicles may not be present.

The lead or dominant follicle will accelerate in growth, from about day 10 to produce a follicle approximately 20 mm in diameter, by approximately day 13 of a 28-day menstrual cycle.

Ovulation will occur shortly afterwards. The oocyte is located on the wall of the follicle, within a cluster of cumulus cells, and is too small to be seen with ultrasound. The follicle becomes the corpus luteum after ovulation.



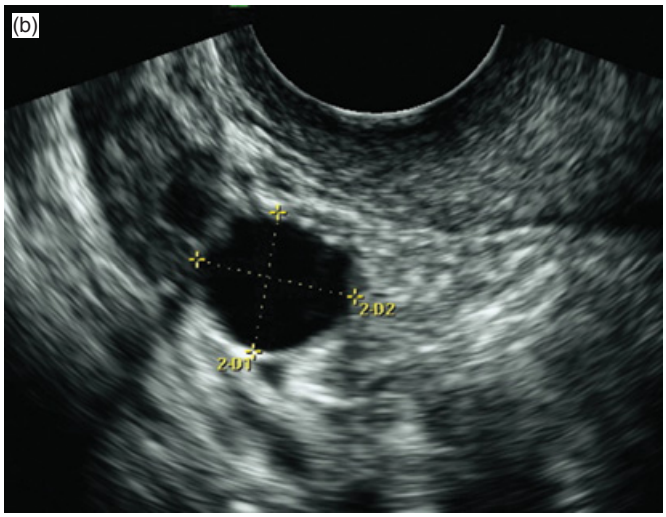


Figure 1.18 (a, b) The left and right ovaries in an unstimulated menstrual cycle. The left ovary contains three small follicles <7 mm and on the right is the developing dominant follicle of 14 mm.

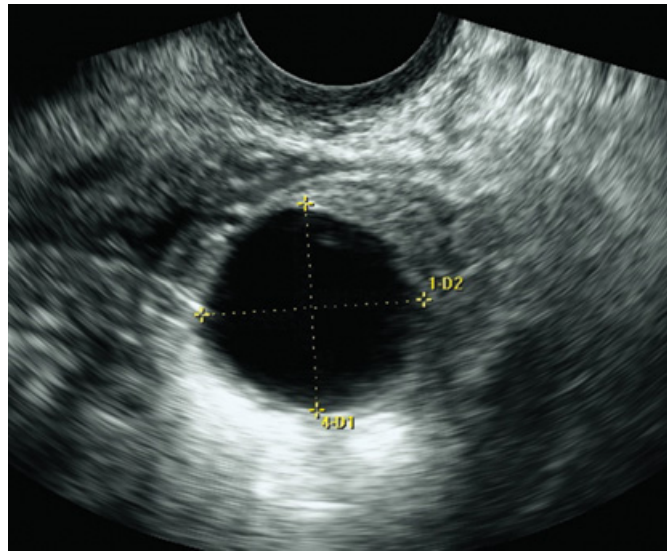


Figure 1.19 The dominant follicle is 24 mm, which will produce a mature ovum.

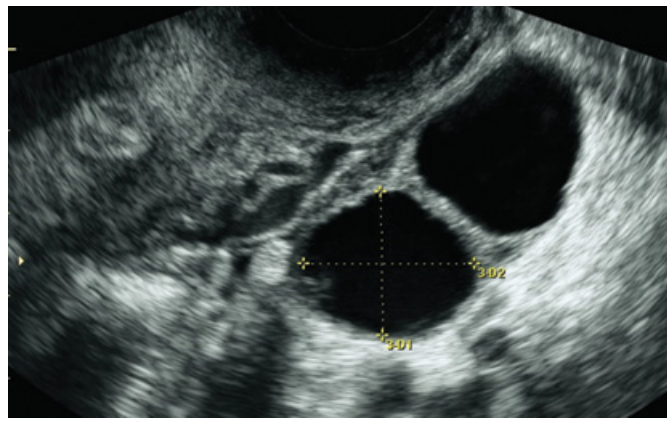


Figure 1.20 Stimulated ovaries may produce more than one mature ovum.

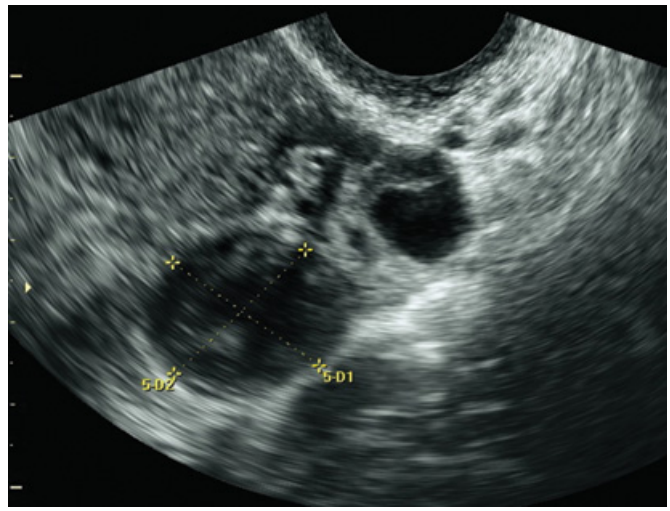


Figure 1.21 Corpus luteum forms post ovulation in the luteal phase of the menstrual cycle.

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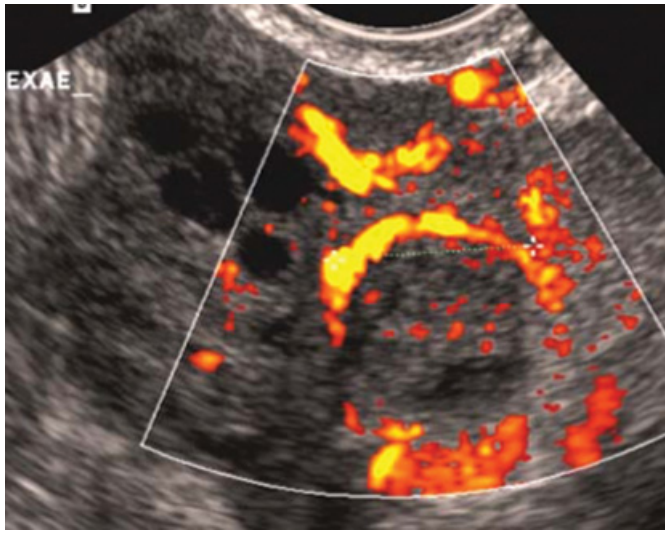

Figure 1.22 Corpus luteum shows the vascular ring with colour Doppler.

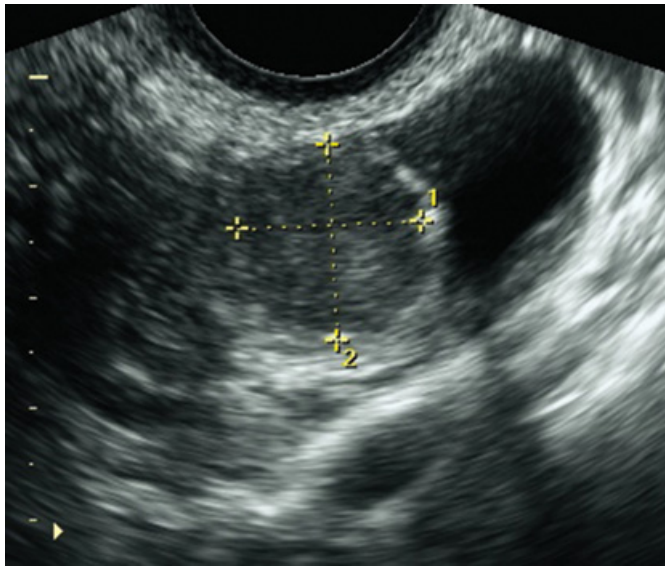

Figure 1.23 Corpus luteum, haemorrhagic cyst and endometrioma may have a similar appearance on ultrasound.

Perimenopausal Ovaries

Ovaries may be difficult to see in the perimenopausal or postmenopausal patient, due to the lack of follicles. The ovarian tissue is identified by location, medial to the iliac vessels and lateral to the uterus and its hypoechoic appearance compared to the surrounding structures. Look closely for small (<3 mm) cysts within the ovary. Figures 1.24 and 1.25

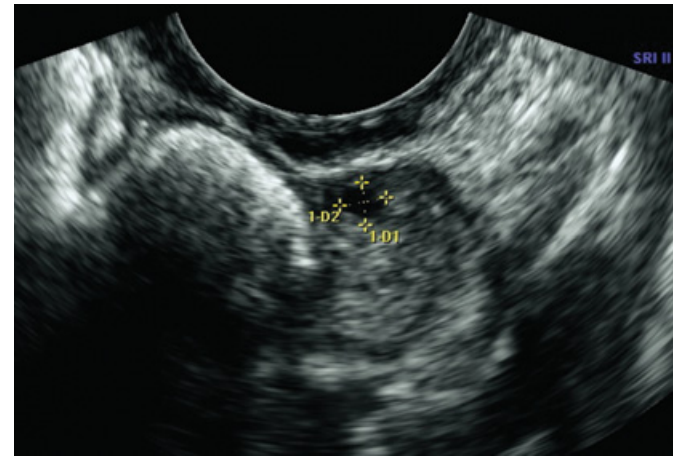

Figure 1.24 Unstimulated ovary.

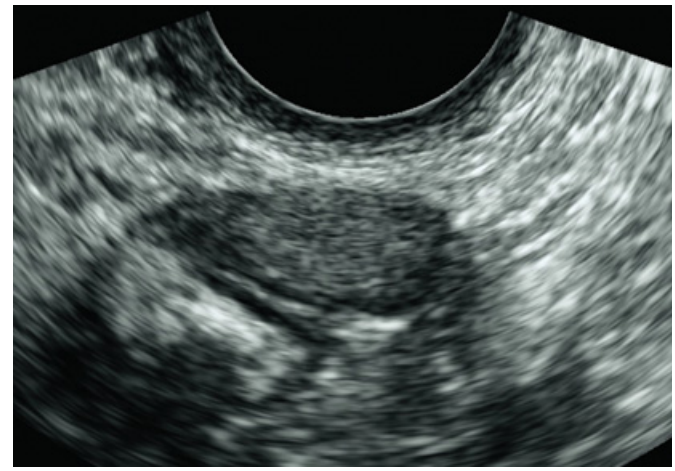

Figure 1.25 Perimenopausal ovary with no defined follicles.

Fluid in the Pelvis

A full bladder is not required for a transvaginal scan. If the bladder is partially filled it is seen as an anechoic structure anterior to the uterus. Figure 1.26

Free fluid may be seen as an anechoic collection in the POD or around the ovaries. The anechoic fluid collection will fill the space between the anatomical structures within the pelvis.

Small pockets of physiological free fluid may be seen in the pelvis.

A small amount of free fluid may be seen at any time during the menstrual cycle and is considered normal in asymptomatic premenopausal women. Figures 1.27, 1.28

Large pockets of free fluid may be due to infection or other medical conditions.

Ovarian hyperstimulation syndrome results in the ultrasound appearance of enlarged ovaries with multiple follicles and free fluid in the pelvis extending into the abdomen and in severe cases in the chest cavity. Figures 1.30, 1.31

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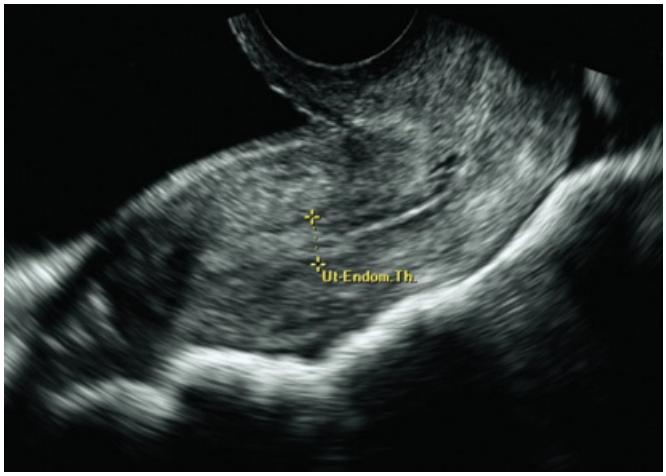

Figure 1.26 Transvaginal scan with a full bladder anterior to the uterus and a physiological small collection posterior to the uterus and in the pouch of Douglas.

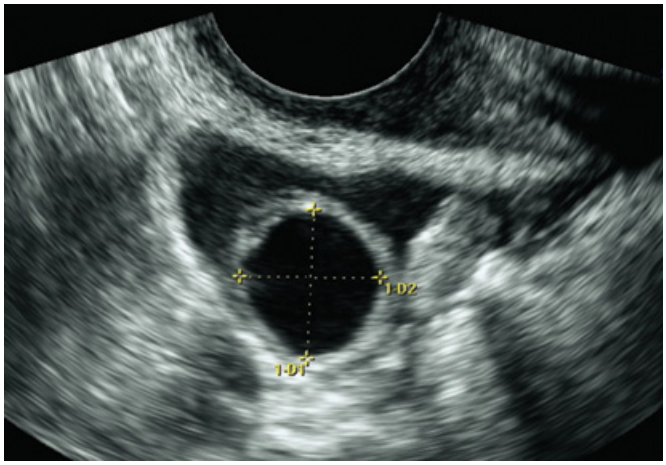

Figure 1.27 Pocket of free fluid around a single ovarian follicle.

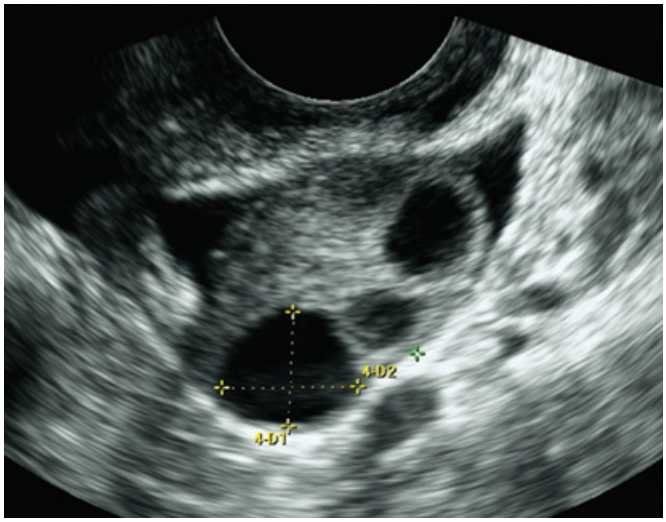

Figure 1.28 The fluid is seen adjacent to the outline of the ovary between the pelvic wall laterally and the uterus medially.

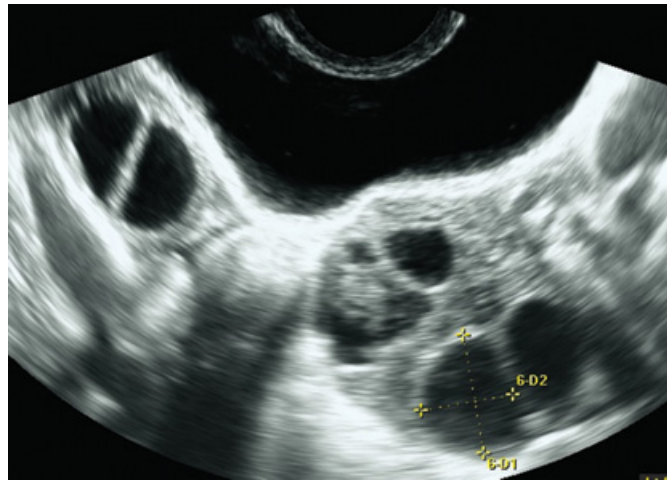

Figure 1.29 The ovaries scanned through the full bladder in this transvaginal study.

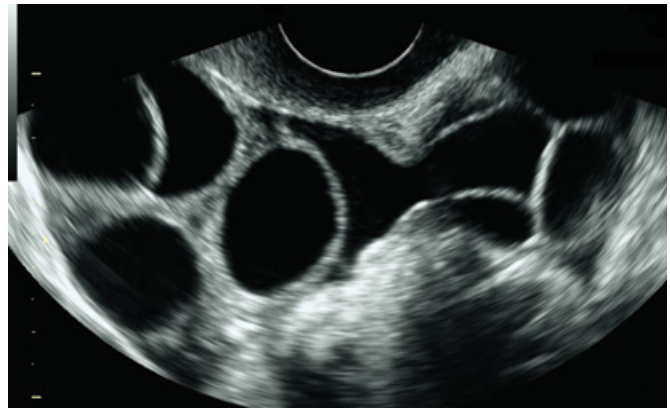

Figure 1.30 Free fluid seen between the right and left ovaries.

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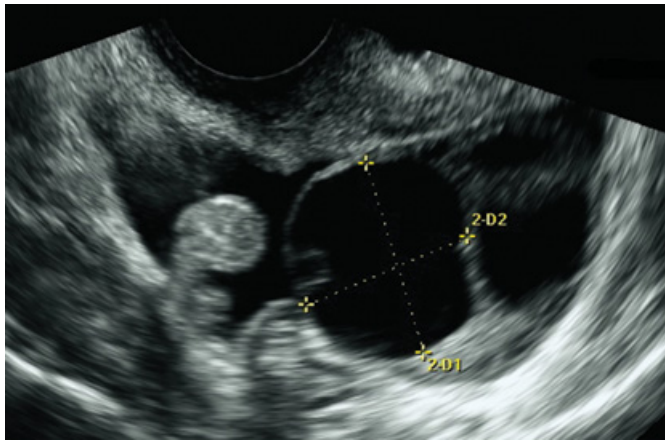

Figure 1.31 Loop of small bowel floating in the free fluid adjacent to the right ovary.

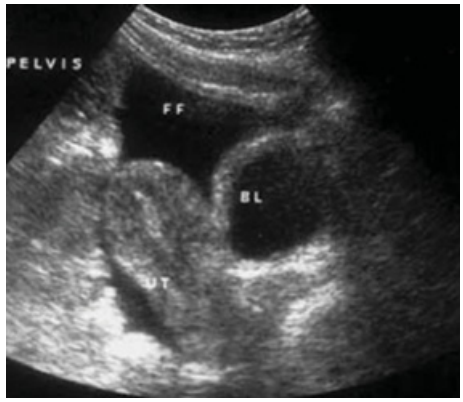

Figure 1.32 Transabdominal scan of the pelvis showing free fluid in excess of 300 ml.

Transabdominal scanning is required to assess large amounts of free fluid in the abdomen. Use the transabdominal approach to investigate the extent of the fluid in the upper abdomen, including Morrison's pouch and above the diaphragm. Figure 1.32

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