Early assessment of ambiguous genitalia
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A multidisciplinary problem

To discover that there is uncertainty about the sex of one’s newborn baby is devastating and often incomprehensible for most parents. It is paramount that clear explanations and investigations are commenced promptly, and that no attempt is made to guess the sex of the baby. Extreme sensitivity is required, and ideally the baby should be managed in a tertiary centre by a multidisciplinary team including a paediatric endocrinologist and a paediatric urologist. Early involvement of a clinical psychologist with experience in this field should be mandatory. Other professionals including geneticists and gynaecologists may also become involved. There must be access to specialist laboratory facilities and experienced radiologists. The incidence of genital ambiguity that results in the experienced radiologists. The incidence of genital ambiguity that results in the experienced radiologists. The incidence of genital ambiguity that results in the experienced radiologists. 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The incidence of genital ambiguity that results in the experienced radiologists. The incidence of genetic sex (through duplication of Xp21) and Wnt4 (through duplication of 1p35), have been associated with impaired gonadal development and undervirilisation in a small number of karyotypic 46 XY males. Mutations or duplications in the various genes responsible for gonadal differentiation and the subsequent development of the internal and external genital phenotype genes may be responsible for gonadal dysgenesis and in some cases complete sex reversal (table 1).

Wnt4 is also expressed in the Müllerian ducts and in the absence of anti-Müllerian hormone (AMH) (also known as Müllerian inhibiting substance) and testosterone, Müllerian structures develop, while the Wolffian ducts involute. AMH promotes regression of Müllerian structures and as the only source of AMH in the fetus is the testes, the absence of a uterus in a baby with ambiguous genitalia is evidence that there has been functional testicular tissue (Sertoli cell) present. Testosterone produced from Leydig cells promotes differentiation of the Wolffian ducts and hence the internal male genitalia (vas deferens, epididymis, and seminal vesicles).

Testosterone is converted to dihydrotestosterone [DHT] by the enzyme 5x-reductase. DHT masculinises the external genitalia from about 6 weeks gestation, and the degree of masculinisation is determined by the amount of fetal androgen present (irrespective of source) and the ability of the tissues to respond to the androgens.

Defects in any part of this pathway (including gene mutations and chromosomal abnormalities (for example, 46XY/46XX, 45X/46XY), inappropriate hormone levels, or end-organ unresponsiveness) may result in genital ambiguity, with undervirilisation of an XY individual, virilisation of an XX individual, or the very rare true hermaphrodite (an individual with both ovarian tissue with primary follicles and testicular tissue with seminiferous tubules which may be in separate gonads or ovotestes).

CLINICAL ASSESSMENT OF AMBIGUOUS GENITALIA

History
The history should include details of the pregnancy, in particular the use of any

Abbreviations: AMH, anti-Müllerian hormone; CAH, congenital adrenal hyperplasia; DHEA, dehydroepiandrosterone; DHEAS, dehydroepiandrosterone sulphate; DHT, dihydrotestosterone; EUA, examination under anaesthesia; HCG, human chorionic gonadotrophin; STARD, steroidogenic acute regulatory protein.
drugs (table 2) that may cause virilisation of a female fetus and details of any previous neonatal deaths (which might point to an undiagnosed adrenal crisis). A history of maternal virilisation may suggest a maternal androgen secreting tumour or aromatase deficiency. A detailed family history should be taken, including whether the parents are consanguineous (which would increase the probability of an autosomal recessive condition) or if there is a history of genital ambiguity in other family members (for example, an X-linked recessive condition such as androgen insensitivity).

Examination

The general physical examination should determine whether there are any dysmorphic features and the general health of the baby. A number of syndromes are associated with ambiguous genitalia, for example, Smith-Lemli-Opitz syndrome (characterised by hypcholesterolaemia and elevated 7-dehydrocholesterol levels, and resulting from mutations affecting 7-dehydrocholesterol reductase), Robinow syndrome, Denys-Drash syndrome, and Beckwith-Wiedemann syndrome. Midline defects may point towards a hypothalamic-pituitary cause for microopenis and cryptorchidism. Hypoglycaemia may indicate cortisol deficiency secondary to hypothalamic-pituitary or adrenocortical insufficiency. The state of hydration and blood pressure should be assessed as various forms of congenital adrenal hyperplasia (CAH) can be associated with differing degrees of salt loss, varying degrees of virilisation in girls or undervirilisation in boys.

Figure 1 Normal sexual differentiation. SRY, sex determining region on Y chromosome; TDF, testis determining factor; AMH, anti-Müllerian hormone; T, testosterone; DHT, dihydrotestosterone; WT1, Wilms’ tumour suppressor gene; SF1, steroidogenic factor 1; SOX9, SRY-like HMG-box; Wnt4, Wnt-4 a group of secreted signalling molecules that regulate cell to cell interactions during embryogenesis; DAX1, DSS-AHC critical region on the X chromosome.

Table 1 Consequences of mutations/deletions and duplications/translocations of genes involved in gonadal differentiation

<table>
<thead>
<tr>
<th>Gene mutation or deletion (loss of function)</th>
<th>Chromosome location</th>
<th>Gonadal development</th>
<th>Associated disorder</th>
<th>Sex reversal/genital ambiguity</th>
<th>Müllerian development</th>
</tr>
</thead>
<tbody>
<tr>
<td>WT1</td>
<td>11p13</td>
<td>Dysgenesis (♂ and ♀)</td>
<td>WAGR syndrome</td>
<td>Genital ambiguity (♂)</td>
<td>Variable (♂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Denys-Drash syndrome</td>
<td>Sex reversal or genital ambiguity (♂)</td>
<td>Variable (♂)</td>
</tr>
<tr>
<td>SF1</td>
<td>9q33</td>
<td>Dysgenesis (♂)</td>
<td>Frasier syndrome</td>
<td>Sex reversal (♂)</td>
<td>Yes (♂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adrenal failure</td>
<td>Sex reversal (♂)</td>
<td>Yes (♂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sex reversal or genital ambiguity (♂)</td>
<td>(variable)</td>
</tr>
<tr>
<td>SRY</td>
<td>Yp11.3</td>
<td>Dysgenesis (♂)</td>
<td>Adrenal failure and hypogonadal failure</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hypogonadal/defective spermatogenesis</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Campomelic dysplasia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DAX1</td>
<td>Xp21</td>
<td>Dysgenesis (♂)</td>
<td>Sex reversal or genital ambiguity (♂)</td>
<td>Variable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOX9</td>
<td>17q24.3–25.1</td>
<td>Dysgenesis or ovarioustic testis</td>
<td></td>
<td></td>
<td>Variable (♂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Campomelic dysplasia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AMH</td>
<td>19p 13.3–13.2</td>
<td>Normal</td>
<td>Sex reversal or genital ambiguity (♂)</td>
<td>Variable</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gene duplication or translocation (gain of function)</th>
<th>Chromosome location</th>
<th>Gonadal development</th>
<th>Associated disorder</th>
<th>Sex reversal/genital ambiguity</th>
<th>Müllerian development</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRY Y fragment</td>
<td>Yp11.3</td>
<td>♀→♂ testis</td>
<td>Sex reversal or genital ambiguity (♂)</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>DAX1 duplication</td>
<td>dupXp21</td>
<td>♀→♂ testis</td>
<td>Sex reversal or genital ambiguity (♂)</td>
<td>Variable</td>
<td></td>
</tr>
<tr>
<td>Wnt 4 duplication</td>
<td>Dup 1p25</td>
<td>♀→♂ testis</td>
<td>Genital ambiguity (♂)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>SOX9 duplication</td>
<td>dup17q24.3–25.1</td>
<td>♀→♂ testis</td>
<td>Genital ambiguity (♂)</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

WAGR, Wilms’ tumour, aniridia, genitourinary anomalies, mental retardation; Denys-Drash (exonic mutations) WT1, diffuse mesangial sclerosis; Frasier (intronic mutations) no WT1, focal segmental glomerulosclerosis. Other abbreviations as for fig 1.
or hypertension (table 3). Although the cardiovascular collapse with salt loss and hyperkalaemia in congenital adrenal hyperplasia does not usually occur until between the 4th to 15th day of life and so will not be apparent at birth in a well neonate, it should be anticipated until CAH has been excluded. Jaundice (both conjugated and unconjugated) may be caused by concomitant thyroid hormone or cortisol deficiency. The urine should be checked for protein as a screen for any associated renal anomalies (for example, Denys-Drash/Frasier syndrome).

### Examination of external genitalia and Prader staging

Examination of the external genitalia determines whether gonads are palpable and the degree of virilisation or Prader stage. Prader stages I–V describe increasing virilisation from a phenotypic female with mild clitoromegaly (stage I) to a phenotypic male with glandular hypospadias (stage V) (fig 2).

If both gonads are palpable they are likely to be testes (or ovotestes) which may be normal or dysgenetic. Flat finger palpation from the internal ring milking down into the labial scrotal folds may detect the presence of a gonad. They may be situated high in the inguinal canal so careful examination is required. A unilateral palpable gonad may be a testis, ovotestis, or rarely an ovary within an inguinal hernia. Congenital adrenal hyperplasia must be excluded in a phenotypically male baby with bilateral undescended testes.

The length of the phallus should be determined. The normal term newborn penis is about 3 cm (stretched length from pubic tubercle to tip of penis) with micropenis less than 2.0–2.5 cm, although this does vary slightly depending on ethnic origin.5 Chordee should be noted as this may decrease the apparent length of the phallus and the penis may be “buried” in some cases. The presence of hypospadias and the position of the urethral meatus should be determined. The urine may be coming from more than one orifice. The degree of fusion and rugosity of the labioscrotal folds should be noted and the presence or absence of a separate vaginal opening determined.

Hyperpigmentation, especially of the genital skin and nipples occurs in the presence of excessive ACTH and proopiomelanocortin and may be apparent in babies with CAH. The gestation of the baby can cause confusion—in preterm girls the clitoris and labia minora are relatively prominent and in boys, the testes are usually undescended until about 34 weeks gestation.

### INVESTIGATIONS

Initial investigations ascertain whether the child is an undervirilised male or a virilised female and from these a differential diagnosis can be established and subsequent investigations planned (fig 3). The principal aims of the initial investigations are to determine the most appropriate sex of rearing and in a genetic female, to exclude CAH and avert a salt losing crisis. Rarer forms of CAH (steroidogenenic acute regulatory protein (STAR) deficiency, 3β-hydroxysteroid dehydrogenase deficiency) may also present with an adrenal crisis in undervirilised males.

### Karyotype

As the differential diagnosis and a number of subsequent investigations will depend on the genetic sex, an urgent karyotype should be sent. Rapid FISH studies using probes specific for the X (DX1) and Y (SRY) chromosomes can provide useful information, although a full karyotype is required for confirmation and exclusion of mosaicism. The latter may be tissue specific and may not be apparent from blood, but only from skin or gonadal biopsies. In cases with a mosaic karyotype, for example, XO/XY or XX/XY, the gonads are often different. This may involve one being a streak gonad and the other a testis or ovotestis, or two ovotestes with different ovarian and testicular components.

### Determination of internal anatomy

As with the external genitalia, the degree of virilisation of the internal genital tracts is defined by Prader stages I–V (fig 2). The anatomy of the vagina or urogenital sinus and uterus may be determined by ultrasound, and if necessary, further delineation by EUA/cystoscopy or urogenital sinogram. Ultrasound is also useful in excluding associated renal anomalies, particularly if Denys-Drash syndrome is suspected or proven. It may also be used to visualise the adrenal glands. Ultrasound may also locate inguinal gonads, although it is not sensitive for intra-abdominal gonads. Ultrasound sensitivity and accuracy depend on probe resolution; an experienced ultrasonographer is required. Identification of the gonads may require magnetic resonance imaging (MRI) or laparoscopy. These latter investigations are also useful for determining the anatomy of the internal

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**Table 2** Disorders of sex differentiation

<table>
<thead>
<tr>
<th>Classification</th>
<th>Details</th>
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<tbody>
<tr>
<td><strong>Virilisation of XX females</strong></td>
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<tr>
<td>Increased fetal adrenal androgen production</td>
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<tr>
<td>Congenital adrenal hyperplasia (3β-hydroxysteroid dehydrogenase deficiency, 21-hydroxylase deficiency, 11β-hydroxylase deficiency)</td>
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<tr>
<td>Androgen secreting tumour</td>
<td></td>
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<tr>
<td>Placental aromatase deficiency</td>
<td></td>
</tr>
<tr>
<td>Fetal gonadal androgen production</td>
<td></td>
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<tr>
<td>True hermaphrodite with both testicular and ovarian tissue</td>
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<tr>
<td>Transplacental passage of maternal androgens</td>
<td></td>
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<tr>
<td>Drugs administered during pregnancy: e.g. progesterone, danazol</td>
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<tr>
<td>Maternal androgen secreting tumour, luteoma of pregnancy</td>
<td></td>
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<tr>
<td>Other causes</td>
<td></td>
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<tr>
<td>Dysmorphic syndromes</td>
<td></td>
</tr>
<tr>
<td>Prematurity—prominent clitoris</td>
<td></td>
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<tr>
<td>Hermaphroditism. Usual genotype 46XX</td>
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</tbody>
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**Undervirilisation of XY males**

<table>
<thead>
<tr>
<th>Type</th>
<th>Details</th>
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<tbody>
<tr>
<td>Testicular dysgenesis/malfunction</td>
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<tr>
<td>Pure XY gonadal dysgenesis</td>
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<tr>
<td>Mixed gonadal dysgenesis 45X/46XY</td>
<td></td>
</tr>
<tr>
<td>May be associated with gene mutations on SRY, SOX9, or WT1 genes</td>
<td></td>
</tr>
<tr>
<td>Dysgenetic testis</td>
<td></td>
</tr>
<tr>
<td>Testicular regression syndromes</td>
<td></td>
</tr>
<tr>
<td>True androgenic, rudimentary testis syndrome</td>
<td></td>
</tr>
<tr>
<td>Biosynthetic defect—decreased fetal androgen biosynthesis</td>
<td></td>
</tr>
<tr>
<td>Leydig cell hypoplasia (LH deficiency or LH receptor defect)</td>
<td></td>
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<tr>
<td>Testosterone biosynthesis (non-virilising CAH): (StAR, 3β-HSD, 17α-OHD/17–20 lyase, Smith-Lemli-Opitz syndrome)</td>
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<tr>
<td>5α-reductase deficiency</td>
<td></td>
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<tr>
<td>Deficient synthesis or action of ANH—persistent Mullerian duct syndrome. May be due to mutations in AMH or AMH receptor gene or SF1 gene</td>
<td></td>
</tr>
<tr>
<td>End organ unresponsiveness</td>
<td></td>
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<tr>
<td>Androgen receptor and post-receptor defects (complete and incomplete androgen insensitivity syndrome)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
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<tr>
<td>Urogenital malformations</td>
<td></td>
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<tr>
<td>Dysmorphic syndromes</td>
<td></td>
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<tr>
<td>Exogenous maternal oestrogens</td>
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</table>
There are a variety of different forms of CAH, each with specific genetic causes and clinical presentations. The forms of CAH causing genital ambiguity in the newborn are detailed in Table 3.

Table 3 Forms of CAH causing genital ambiguity in the newborn

<table>
<thead>
<tr>
<th>Type of CAH</th>
<th>StAR protein deficiency</th>
<th>3β-HSD</th>
<th>17α-OHD</th>
<th>11β-OHD</th>
<th>21-OHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt wasting</td>
<td>Yes</td>
<td>Yes</td>
<td>Hypertension</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Enzyme P-450c 1A2</td>
<td>P-450c17</td>
<td>DOC</td>
<td>Corticosterone</td>
<td>DOC, 11-deoxycorticosterone</td>
<td>Cortisol, aldosterone</td>
</tr>
<tr>
<td>Steroids 1, All</td>
<td>HSD3B2</td>
<td>CYP17</td>
<td>CYP11B1</td>
<td>CYP21</td>
<td></td>
</tr>
<tr>
<td>Steroids 2, All</td>
<td>NADH</td>
<td>10Q24.3</td>
<td>8Q24.3</td>
<td>6P21.3</td>
<td></td>
</tr>
</tbody>
</table>

StAR protein, steroidogenic acute regulatory protein deficiency, otherwise known as lipid hyperplasia/cholesterol desmolase deficiency; 3β-HSD, 3β-hydroxysteroid dehydrogenase deficiency; 17α-OHD, 17α-hydroxylase deficiency; 11β-OHD, 11β-hydroxylase deficiency; 21-OHD, 21-hydroxylase deficiency; DOC, 11-deoxycorticosterone; DHEA, dehydroepiandrosterone; 17-OHP, 17α-hydroxyprogesterone; 17α-OH-preg, 17α-hydroxyprogrenolone; A4, androstenedione.

To determine whether functioning Leydig cells are present, a hCG stimulation test is undertaken. This is also used to delineate a block in testosterone biosynthesis from androstenedione (17β-hydroxysteroid dehydrogenase deficiency) or conversion of testosterone to DHT (5α-reductase deficiency). There are a variety of protocols for the hCG test, but essentially it involves taking baseline samples for testosterone and its precursors dehydroepiandrosterone (DHEA) (or DHEA sulphate (DHEAS)) and androstenedione and its metabolite (DHT). One to three intramuscular injections of high dose hCG (500–1500 IU) are given at 24 hour intervals and repeat androgen samples are taken at 72 hours or 24 hours after the last injection. The neonatal gonad is more active than at any time in childhood until puberty, reaching a peak at about 6-8 weeks of age. A balance needs to be reached between performing the hCG test when the gonad is normally most active (testosterone secretion normally rises in the fourth week of life, peaking at 1–3 months) and proceeding with the investigations as promptly as possible. While some would advocate that this test is deferred beyond 2 weeks of age, this may not be necessary. In the newborn period an increase in testosterone, reaching adult male levels, would normally be expected after hCG.

The hCG test can be extended to a three week test if the three day hCG test is inconclusive. The same dose of hCG is administered twice weekly for three weeks and testosterone, DHT, and androstenedione samples taken 24 hours after the last hCG injection. The clinical response in terms of testicular descent and change in the size of the phallus and frequency of erections should be documented. Photographs pre- and post-hCG, may be helpful.

Anti-Müllerian hormone (AMH) and inhibit B levels

While hCG stimulation tests the function of the Leydig cells, both AMH and inhibit B are secreted by the Sertoli cells. Inhibit B is detectable for the first six months, rising again at puberty. AMH levels are high in human male serum postnatally for several years before declining during the peripubertal period, but AMH is undetectable in female serum until the onset of puberty. AMH may prove to be a more sensitive marker for the presence of testicular tissue than serum testosterone levels, both before and after the neonatal androgen surge, and, consequently, may obviate the need for hCG stimulation in the evaluation of certain intersex disorders. Similarly, basal inhibit B has been shown to predict the testosterone response to hCG in boys, and therefore may give reliable information about both the presence and function of the tests. Furthermore, inhibit B levels have been shown to demonstrate specific alterations in patients with genital ambiguity which may aid the differential diagnosis of male undervirilisation.

However, these assays are not routinely available in the UK.

Assessment of gonadotrophins

Assessment of the gonadotrophins may give useful information. Raised basal gonadotrophins are consistent with primary gonadal failure. The gonadotrophin response to GnRH is difficult to interpret in the prepubertal child unless exaggerated, which is consistent with gonadal failure but adds little to the basal levels alone. Pituitary failure would give a flat response but is not diagnostic, and hypothalamic abnormalities such as Kallmann’s syndrome are not excluded by a “normal” response. The optimal time to assess this is within the first six months of life when there is a gonadal surge in both sexes (girls greater than boys), and the axis is hence maximally responsive.

Assessment of adrenal function

Urinary steroid profile

Output of adrenal steroids will be low in adrenal insufficiency. In CAH specific ratios of metabolites will be altered, depending on the level of the enzyme block.

Synacthen test

A standard short Synacthen test is useful in the following situations:

- Suspected CAH where a peak 17-hydroxyprogesterone (17-OHP) of 100–200 nmol/l is suggestive of 21-hydroxylase deficiency. (Higher reference ranges for preterm infants.)
- Suspected CAH to assess adrenal cortical reserve (measurement of cortisol levels).

The dose of Synacthen is dependent on local protocol (example 36 μg/kg or a standard dose of 62.5 μg intravenously or intramuscularly). Cortisol and 17-OHP levels are normally measured at 0 and 30 minutes only as the 60 minute
value does not usually contribute further. A normal basal value, or even a normal stimulated response does not exclude the evolution of adrenal insufficiency, and may need to be repeated depending on clinical suspicion. A basal ACTH level may be helpful, but in most laboratories the turnaround time is slower than for cortisol.

Skin and gonadal biopsies
Genital skin biopsies (2–4 mm) performed at the time of examination under anaesthesia (EUA) or genitalplasty are useful to establish cell lines for androgen receptor binding assays and analysis of 5α-reductase activity. The cell line is also a source of genomic DNA and RNA and/or subsequent molecular and functional studies. Karyotype analysis for the presence of mosaicism may be indicated. Gonadal biopsies are essential when considering diagnostic categories such as dysgenesis and true hermaphroditism. A detailed histopathological report is essential. As special treatment of the samples may be required, prior discussion with the pathologist or genetics laboratory should take place.

INTERPRETATION OF RESULTS
Genital ambiguity with a 46XX karyotype indicates a virilised female
The female fetus with ovaries and normal internal genitalia has been exposed to excessive testosterone, and hence dihydrotestosterone (by conversion of testosterone by 5α-reductase) which virilises the external genitalia. The androgens may be derived from the fetal adrenal gland (CAH and placental aromatase deficiency), fetal gonad (the testis or ovotestis in true hermaphroditism), or rarely, exogenously via transplacental passage from the mother (adrenal or ovarian tumours).

Absence of palpable gonads in association with otherwise apparently male genitalia should always alert one to the possibility of a virilised female. By far the commonest cause of this is CAH. Of the enzyme defects that cause virilisation in female fetuses, 21-hydroxylase deficiency, by inhibiting the conversion of androgens to oestrogens, may cause virilisation in female fetuses, and in addition, maternal virilisation occurs from placental transfer of the excessive androgens.17

Table 2 lists conditions that cause virilisation of a female fetus.

Genital ambiguity with a 46XY karyotype indicates an undervirilised male
This is a genetically XY male with two testes, but whose genital tract fails to differentiate normally. There are numerous presentations of genital anomaly, from apparently normal female (Prader I) with a palpable tumour (she may be virilised as a result) or from drugs given during pregnancy. Placental aromatase deficiency, by inhibiting the conversion of androgens to oestrogens, may cause virilisation of a female fetus, and in addition, maternal virilisation occurs from placental transfer of the excessive androgens.17

If the gonads are palpable, they are likely to be testes (or rarely ovotestes). Investigations are directed at determining the anatomy of the internal genitalia, and establishing whether the testicular tissue is capable of producing androgens. Investigations that may help with the former include pelvic ultrasound, examination under anaesthesia with cystoscopy and laparoscopy. Genital skin biopsy specimens can be taken at the time of endoscopies. Occasionally urogenital sinogram or

Figure 3 Investigation flow plan for assessment of ambiguous genitalia.
MRI can be helpful. Laparoscopy/laparotomy and gonadal biopsy may be required.

**Testicular dysgenesis/malfunction**

A 46 XY karyotype, with low basal and hCG stimulated testosterone and low testosterone precursors suggests either gonadal dysgenesis (which may require laparoscopy and testicular biopsy) or lipidoid CAH (caused by an abnormality in the steroidogenic acute regulatory [STAR] protein).

In the latter condition total adrenal failure is confirmed on Synacthen test, electrolytes, and urinary steroids. Because of the other associated gene defects (table 1), there may be other anomalies such as bony dysplasias or renal anomalies, which should be looked for.

The poorly functioning testicular tissue is likely to give a subnormal testosterone response to hCG and basal gonadotrophins will usually be increased, consistent with primary gonadal failure. In addition, the dysoesthetic testes may secrete inadequate amounts of anti-Müllerian hormone, and Müllerian structures may be present (although often hypoplastic) in children with gonadal dysgenesis and a 46XY karyotype.

A mosaic karyotype, for example 45X/46XY suggests gonadal dysgenesis. There is a very variable phenotype both in terms of internal and external genitalia, which is not dependent on the percentage of each karyotype as determined by lymphocyte analysis. Over 90% of individuals with prenatally diagnosed 45X/46XY karyotype have a normal male phenotype, suggesting most individuals with this karyotype escape detection and that an ascertaining bias exists towards those with clinically evident abnormalities.1, 3

**Biosynthetic defect**

A 46XY karyotype, low basal and hCG stimulated testosterone levels with increased testosterone precursors indicates a testosteron biosynthetic defect.

Those forms of CAH that cause under-virilisation of male genitalia include 17α-hydroxylase/17,20-lyase deficiency and 3β-hydroxysteroid dehydrogenase deficiency (table 3).

The conversion of androstenedione to testosterone occurs predominantly in the gonad and a post-hCG stimulated ratio of androstenedione to testosterone of >20:1 suggests 17β-hydroxysteroid dehydrogenase deficiency. A urine steroid profile is generally not helpful in this diagnosis before puberty. Molecular analysis of the HSD III gene (HSD17B3) is sought as confirmation of the diagnosis.

**End-organ unresponsiveness**

A 46XY karyotype with genital ambiguity, normal or increased basal and peak testosterone on hCG test, and a normal T:DHT ratio points to partial androgen insensitivity.

There is a variable phenotype, and sex of rearing depends on the degree of phallic development, and sometimes cultural considerations. The child may benefit from a trial of topical DHT cream or intramuscular testosterone (for example using 12.5–25 mg, monthly for three months) on penile growth to help anticipate response in puberty.

The diagnosis is suggested by showing an abnormality in androgen binding in genital skin fibroblasts, or a mutation in the androgen receptor gene. This requires DNA and a genital skin biopsy, taken at the time of EUA or genital surgery. Despite clear evidence of a phenotype consistent with partial androgen PAIS and normal production and metabolism of androgens, only a minority of patients are found to have an androgen receptor gene mutation. The likelihood of finding a mutation is increased if there is a family history consistent with X linkage. The majority of XY infants with undervirilisation remain unexplained.

**DNA analysis**

Many of the causes of genital ambiguity have a genetic basis, and in these cases genetic counselling will be required. For example, androgen insensitivity syndrome is X-linked recessive, and CAH is autosomal recessive. In addition, identification and characterisation of a number of mutations of the genes involved in sexual differentiation has resulted in DNA tests which can be used in prenatal diagnosis. Identification of carriers will facilitate genetic counselling.

**Congenital adrenal hyperplasia**

Several laboratories within the UK will undertake DNA analysis for this condition. Once the diagnosis has been made, a DNA sample from the proband should be taken. If a gene mutation is identified, the carrier status of the parents may be determined and the family should be counselled about the possibility of antenatal screening of subsequent pregnancies, and of steroid treatment of the mother in an attempt to reduce virilisation of a subsequent affected female fetus. In the UK, antenatal diagnosis and treatment is offered as part of a national British Society for Paediatric Endocrinology and Diabetes supported study monitoring efficacy, short and long term side effects, and outcome measures.

**Androgen insensitivity**

DNA analysis is now being undertaken in Cambridge as part of a molecular genetics service in collaboration with Professor Ieuan Hughes. Samples are only analysed following collection of clinical, biochemical, and histological data that are consistent with an androgen insensitive pathophysiology.

**Suspected 5α-reductase deficiency and 17β-hydroxysteroid dehydrogenase deficiency**

DNA samples in patients with suspected 5α-reductase deficiency and 17β-hydroxysteroid dehydrogenase deficiency can also be processed through the Cambridge laboratory.

**Unusual cases of sexual ambiguity**

Mutations of developmental genes such as DX1, SOX9, and WT1 may account for rarer cases of sexual ambiguity. Samples should be taken and DNA extracted and either stored or forwarded to the relevant laboratories, depending on clinical suspicion.
ASSIGNMENT OF SEX OF REARING

A decision about the sex of rearing should be made as soon as is practicable, usually based on the internal and external genital phenotype and the results of the various investigations. Cultural aspects may also be important in cases of severe ambiguity. Assignment of sex of rearing can be extremely difficult, particularly as there is a paucity of data on long term outcome in this area.

In the case of a virilised female (usually CAH), there is usually the potential for fertility and these babies are usually raised as girls. This is much easier if the diagnosis of CAH is made early.

Decisions about nature and timing of any surgery are made with the family acknowledging the considerable psychological impact of having a child with genital ambiguity. There is considerable debate as to the optimal timing of any genital surgery. In the presence of marked clitoromegaly, clitoral reduction genital surgery is usually undertaken in infancy. Lesser degrees of clitoral enlargement may be left until puberty when the child can be involved with the decision making. The timing of any vaginoplasty is dependent on the anatomy of the internal and external genitalia and influenced by the timing of any androgen exposure and the decision of sex of rearing need careful consideration within a multidisciplinary environment with full informed consent of the family.

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