Endocrine Dynamic Function
Test Protocols for use in
Neonates & Children

Royal Manchester Children’s Hospital

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# Endocrine Dynamic Function Test Protocols for use in Neonates and Children

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Guidance

- Please read all protocols carefully to ensure that the lab is notified before any test which requires urgent analysis of specimens once commenced. If notification of the lab is required, this will be indicated at the start of the protocol.

- It is essential that all dynamic function test samples are accompanied with correctly completed request forms which state the test being carried out, the time of each sample and the time of any drug dosage.

- The time point from the dynamic function test protocol MUST be indicated on the blood sample tube.

- In order to minimise haemolysis, a 22 gauge, blue cannula should be used to collect blood samples.

- The volume of blood stated in these protocols assumes that there is a normal packed cell volume (PCV). If the child is known to have a high PCV, then please allow for this and send a larger volume of blood.

- Some of the blood samples required in these protocols need to arrive at the lab very urgently and on ice. Urgent porter delivery is arranged with Sodexo, who have a list of tests which have a porter response time of 5 min. These are termed 'Code Blue' tests. This form of words must be used when contacting the Sodexo helpdesk on x4850. In all cases the requesting clinician must contact the lab before the specimen is sent.
  - ACTH 15 min on ice
  - AVP 5 min on ice
  - Calcitonin 5 min on ice
  - Insulin / C-Peptide 30 min on ice

- Whilst some dynamic function tests may be requested via a specific test name on CWS, not all tests are set up in this way. If a test is being carried out which does not have a CWS test name, please order the analytes individually, indicating in the clinical details which test is being carried out.
Standard Dose Synacthen Test for Suspected Adrenal Failure

CWS test name: SYNACHTHEN(C)

Principle
Adrenal glucocorticoid secretion is controlled by adrenocorticotrophic hormone (ACTH) released by the anterior pituitary. This test evaluates the ability of the adrenal cortex to produce cortisol after stimulation by synthetic ACTH (tetracosactrin: Synacthen). The Synacthen test is a useful investigation in suspected secondary adrenal insufficiency as it correlates reasonably well with the ‘gold-standard’ insulin tolerance test, but is safer and less unpleasant. Chronic ACTH deficiency results in adrenal atrophy which leads to a reduced response to exogenous ACTH.

Indication
- Screening test for suspected adrenal insufficiency.

Precautions
- The Synacthen test is unreliable if performed within 4 weeks of pituitary surgery as ACTH deficiency may not have been sufficiently prolonged to result in adrenal atrophy. An 8 - 9 am plasma ACTH and cortisol can be informative in these situations.
- The test is unreliable in patients taking the oral contraceptive pill.

Side Effects
- Severe allergic reactions to Synacthen have been described, particularly in children with a history of allergic disorders, but are very rare.

Preparation
- The test should preferably be performed in the morning between 0800 and 0900 hrs.
- The patient does not need to be fasted.
- All glucocorticoid therapy (other than dexamethasone or betamethasone) interferes with the assay of cortisol. If the patient is on prednisolone therapy, this must be discontinued for 24 hours prior to the test. If the patient is on a supra-physiological dose of hydrocortisone, this should be reduced to a physiological level (6 mcg/m²/day) prior to the test. Omit the dose the night before and on the morning of the test. If the paediatric endocrine consultant is very anxious about the degree of adrenal insufficiency, then omit only the morning hydrocortisone dose. However, the patient should take their usual dose of corticosteroid as soon as the test is completed.

Protocol
A number of different protocols with different synacthen doses are available. We have taken a pragmatic approach, considering the ease of use.

1. Insert a reliable cannula and, if possible, rest the patient for 30 minutes.
2. Take basal blood sample for cortisol (t = 0).
3. Give Synacthen as an i.v. bolus
   For children 1 - 12 months use a dose of 125 mcg
   For children > 1 yr use a dose of 250 mcg
4. Take a blood sample at + 30 min after Synacthen for cortisol.

Samples
Cortisol 1 mL lithium heparin (orange top) or clotted blood (white top)

Record sample collection times and time of Synacthen administration on the request form.

Interpretation
- A normal response is an increase in plasma/serum cortisol to a level of ≥550 nmol/L at 30 minutes.
- An impaired response does not distinguish between adrenal and pituitary failure, as the adrenal glands may be atrophied secondary to ACTH deficiency.
The dose of Synacthen used is supra-physiological and may give a normal response in patients with mild adrenal insufficiency.

The sensitivity of the Synacthen test is higher in primary adrenal insufficiency compared with secondary adrenal insufficiency. Sensitivity is particularly low in recent-onset ACTH deficiency (within 4 – 6 weeks of an insult to the pituitary).

Cortisol results may be misleadingly low in the presence of low cortisol binding globulin (for example in severe illness, in conjunction with low albumin).

In patients on long-term glucocorticoids it is difficult to differentiate underlying adrenocortical disorders from the adrenal-suppressive effects of the treatment. A urine steroid profile may also be misleading after only 24 hours off hydrocortisone. The urine steroid lab at King’s College Hospital recommend changing the glucocorticoid to dexamethasone and stimulating with depot Synacthen for up to 5 days before sample collection, unless glucocorticoid treatment has been brief. Please discuss with the paediatric endocrine team and the laboratory.

References
Standard Dose Synacthen Test for Congenital Adrenal Hyperplasia (CAH)

**CWS test name:** SYN’HEN (17-A)

**Principle**
Adrenal glucocorticoid secretion is controlled by adrenocorticotropic hormone (ACTH) released by the anterior pituitary. This test evaluates secretion of cortisol and 17-hydroxyprogesterone (17-OHP) by the adrenal cortex following stimulation with Synacthen. In patients with congenital adrenal hyperplasia (CAH; a group of inherited disorders caused by enzyme defects in the steroid synthetic pathway), cortisol may, or may not, be adequately secreted. However, there is excessive secretion of the precursor steroids proximal to the defective enzyme. The commonest cause of CAH is due to 21-hydroxylase deficiency and in these subjects increased secretion of 17-hydroxyprogesterone (17-OHP) occurs.

**Indication**
- Diagnosis of CAH due to 21-hydroxylase deficiency in children and adults.

**Precautions**
- The Synacthen test gives unreliable results if performed within 4 weeks of pituitary surgery.

**Side Effects**
- Severe allergic reactions to Synacthen have been described, particularly in children with a history of allergic disorders, but are very rare.

**Preparation**
- The test should preferably be performed in the morning between 0800 and 0900 hrs.
- The patient does not need to be fasted.
- All glucocorticoid therapy (other than dexamethasone or betamethasone) interferes with the assay of cortisol. If the patient is on prednisolone therapy, this must be discontinued for 24 hours prior to the test. If the patient is on a supra-physiological dose of hydrocortisone, this should be reduced to a physiological level (6 mcg/m²/day) prior to the test. Omit the dose the night before and on the morning of the test. If the paediatric endocrine consultant is very anxious about the degree of adrenal insufficiency then omit only the morning hydrocortisone dose. However, the patient should take their usual dose of corticosteroid as soon as the test is completed.

**Protocol**
*A number of different protocols with different synacthen doses are available. We have taken a pragmatic approach, considering the ease of use.*

1. Insert a reliable cannula and, if possible, rest patient for 30 minutes.
2. Take basal blood sample for cortisol and 17-OHP (t = 0).
3. **Give Synacthen as an i.v. bolus**
   - For children 1 - 12 months use a dose of 125 mcg
   - For children > 1 yr use a dose of 250 mcg
4. Take blood samples at + 30 min + 60 min after Synacthen for cortisol and 17-OHP

**Samples**
- **Cortisol** 1 mL lithium heparin (orange top) or clotted blood (white top)
- **17–OHP** 1 mL lithium heparin (orange top) or clotted blood (white top)

Record sample collection times and time of Synacthen administration on the request form.
**Interpretation**

- Unaffected adults and children usually have a basal 17-OHP of <6 nmol/L.
- A minority of patients with non-classical CAH have a normal basal 17-OHP, even on early morning samples.
- A normal response to Synacthen is a stimulated 17-OHP of <30 nmol/L at 60 minutes.
- A stimulated 17-OHP (60 minutes post-Synacthen) of 30 - 50 nmol/L is suggestive of CAH but some heterozygotes have levels within this range. Genotyping of the 21-hydroxylase gene may help reach a diagnosis.
- A stimulated 17-OHP of ≥50 nmol/L is consistent with a diagnosis of CAH.
- Milder elevations of 17-OHP may be found in rarer forms of CAH: 11-β-hydroxylase deficiency and 3-β-hydroxysteroid dehydrogenase deficiency.
- An increment of <10 nmol/L in normal individuals compared to >20 nmol/L in CAH has been reported.
- A normal cortisol response is an increase in plasma/serum cortisol to a level of ≥550 nmol/L at 30 minutes.

**References**

**Low Dose Synacthen Test**

**CWS test name:** LD SYNACTHEN

**Principle**
Adrenal glucocorticoid secretion is controlled by adrenocorticotrophic hormone (ACTH) released by the anterior pituitary. This test evaluates the ability of the adrenal cortex to produce cortisol after stimulation by synthetic ACTH (tetracosactrin: Synacthen). The low-dose test is thought to be a more sensitive version of the standard dose Synacthen test, using a physiological rather than a pharmacological dose of Synacthen.

**Indication**
The low-dose test may be indicated in children who have a normal response to the standard dose Synacthen test, but a clinical history (e.g. chronic steroid therapy or symptoms, such as hypoglycaemia), suggestive of adrenocortical insufficiency. Use this low dose test for children who have been on inhaled or topical steroids, on corticosteroid treatment and when partial adrenal insufficiency is suspected.

**Precautions**
- The test is unreliable in patients taking the oral contraceptive pill.
- The dose of Synacthen involved in this test is very low. Great care must be taken with preparation and administration.

**Side Effects**
- Severe allergic reactions to Synacthen have been described, particularly in children with a history of allergic disorders, but are very rare.

**Preparation**
- The patient does not need to be fasted.
- This test can be performed at any time of day
- All glucocorticoid therapy (other than dexamethasone or betamethasone) interferes with the assay of cortisol. If the patient is on prednisolone therapy, this must be discontinued for 24 hours prior to the test. If the patient is on a supra-physiological dose of hydrocortisone, this should be reduced to a physiological level (6 mcg/m²/day) prior to the test. Omit the dose the night before and on the morning of the test. If the paediatric endocrine consultant is very anxious about the degree of adrenal insufficiency then omit only the morning hydrocortisone dose. However, the patient should take their usual dose of corticosteroid as soon as the test is completed.

**Protocol**
1. Insert reliable cannula and rest patient for 30 minutes.
2. Prepare 1 microgram solution of Synacthen from 250 mcg vial as follows:
   - Dilute 1 mL to 50 mL with normal saline giving 250 mcg in 50 mL
   - Take 1 mL of above solution and dilute with 9 mL of saline giving 5 mcg in 10 mL.
   - The diluted dose must be freshly prepared.
3. Take basal blood sample for cortisol (t = 0 min).
4. Administer 2 mL of above solution (1 mcg) to patient i.v.
5. Flush the line with 5 mL saline to ensure that the whole dose has been administered.
6. Take blood samples at + 20 min
   - + 30 min
   - + 40 min
   after Synacthen, for cortisol

**Samples**
- **Cortisol:** 1 mL lithium heparin (orange top) or clotted blood (white top)
**Interpretation**

- A normal response is a peak cortisol level of $\geq 550$ nmol/L. Levels below 550 nmol/L indicate a degree of adrenal insufficiency.

- In patients on long-term glucocorticoids it is difficult to differentiate underlying adrenocortical disorders from the adrenal-suppressive effects of the treatment. A urine steroid profile may also be misleading after only 24 hours off hydrocortisone. The urine steroid lab at King’s College Hospital recommend changing the glucocorticoid to dexamethasone and stimulating with depot Synacthen for up to 5 days before sample collection, unless glucocorticoid treatment has been brief. Please discuss with the paediatric endocrine team and the laboratory.

**References**


Diagnosis & Differential Diagnosis of Cushing’s Syndrome

Cushing’s syndrome comprises a large group of signs and symptoms reflecting prolonged and inappropriately high exposure of tissues to glucocorticoids. Recent Endocrine Society clinical practice guidelines contain recommendations for the diagnosis of Cushing’s syndrome.

Before commencing testing
Exclude the use of excessive exogenous glucocorticoids which may result in iatrogenic Cushing’s syndrome before conducting biochemical testing.

Testing should be initiated in each of the following conditions:
- Patients with unusual features for their age:
  - In children this includes those with decreasing height percentile and increasing weight
- Patients with multiple and progressive features, particularly those more predictive of Cushing’s syndrome. In children this may include:
  - Slow growth
  - Abnormal genital virilisation
  - Short stature
  - Pseudoprecocious puberty or delayed puberty
- Patients with adrenal incidentaloma compatible with adenoma

Initial testing for Cushing’s syndrome should include one of the following tests:
- Urine Free Cortisol (UFC; at least two measurement)
- Midnight salivary cortisol (two measurements)
- 1-mg overnight dexamethasone suppression test (DST)
- Longer low dose DST (2 mg/day for 48 hrs)

Definition of the cause of Cushing’s syndrome should include the following tests:
- 9 am Plasma ACTH
- CRH Test
- Analysis of change in serum cortisol during Low dose dexamethasone suppression test
- Adrenal/Pituitary MRI scan
- Bilateral inferior petrosal sinus sampling for ACTH (with CRH)

The following tests are not recommended in order to test for Cushing’s syndrome:
- Random serum cortisol or plasma ACTH levels
- Urinary 17-ketosteroids
- Insulin tolerance test
- Loperamide test
- Tests designed to determine the cause of Cushing’s syndrome (e.g. pituitary and adrenal imaging, 8 mg DST)

- Abnormal initial test results should be further investigated using a second recommended test.
- Further testing for Cushing’s syndrome of individuals with concordantly negative results on two different tests is not recommended.
- Patients with concordantly positive results from two different tests should be further tested to establish the cause of Cushing’s syndrome, provided there is no concern regarding possible non-Cushing’s hypercortisolism.
- Further evaluation of patients with concordantly negative results may be appropriate in patients suspected of having cyclical disease, especially if the pre-test probability of Cushing’s syndrome is high.

References
**Low Dose Dexamethasone Suppression Test**

**CWS Test Name:** None – Please request tests separately

**Principle**
Cushing's syndrome comprises a large group of signs and symptoms which are the result of prolonged exposure to inappropriately high levels of glucocorticoids. In normal subjects the administration of a supra-physiological dose of glucocorticoid results in suppression of ACTH and cortisol secretion. In endogenous Cushing's syndrome of any cause there is a failure of this suppression when a low dose of the synthetic glucocorticoid dexamethasone is given. The low dose dexamethasone suppression test has been reported to have a sensitivity and specificity of 94% when used to differentiate paediatric patients with Cushing's syndrome from normal individuals. This 48 hour 2 mg/day low dose protocol has improved specificity compared to the overnight test.

**Indication**
- To diagnose Cushing's syndrome

**Precautions**
- False positive results may be obtained following the use of drugs that accelerate dexamethasone metabolism including phenobarbital, phenytoin, carbamazepine, rifampin, rifapentine, ethosuximide, diltiazem or cimetidine. If possible these should be stopped a few weeks prior to the test.
- Drugs that increase cortisol binding globulin (CBG) may also falsely elevate cortisol results including oestrogens.
- Dexamethasone clearance maybe reduced in patients with liver and/or renal failure
- Dexamethasone should be used cautiously in a child with diabetes mellitus with meticulous measurements of blood glucose during the period of the test.
- The child should not be on exogenous glucocorticoids during the test including steroid creams, inhalers and eye drops.

**Side Effects**
- There is no significant effect of short term dexamethasone use

**Preparation**
- None required

**Protocol**

*ACTH samples should be sent IMMEDIATELY to laboratory on ice for centrifugation and freezing*

1. **Day 1** - Take blood samples for cortisol and plasma ACTH at 0900h and 2400h

2. **Days 2 and 3** - Starting at 0900h administer dexamethasone every 6 hours (i.e. 1500, 2100, 0300h) as follows:
   
   a. *If the patient weighs more than 40 kg, use a dose of 0.5 mg dexamethasone*
   
   b. *If the patient weighs less than 40 kg, adjust the dose to 30 mcg/kg/day (divided into 4 daily doses)*

   All doses must be adhered to for the test to be valid

3. **Day 4** - Take blood samples for serum cortisol and plasma ACTH at 0900h, 6 hr after the last dose of dexamethasone.
### Endocrine Dynamic Function Test Protocols for use in Neonates and Children

#### Time Points:

<table>
<thead>
<tr>
<th>Day</th>
<th>Time (h)</th>
<th>Procedure</th>
<th>Sample</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td>Blood for Cortisol/ ACTH</td>
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<td>Blood for Cortisol/ ACTH</td>
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<td></td>
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<td>Blood for Cortisol/ ACTH</td>
</tr>
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</table>

#### Samples

- **ACTH**: 2-3 mL blood in a 5 mL lithium heparin tube (orange top)
  - *Send IMMEDIATELY to laboratory on ice for centrifugation and freezing*

- **Cortisol**: 1 mL lithium heparin (orange top) or clotted blood (white top)

Record sample collection times and time of dexamethasone administration on the request form.

#### Interpretation

- If the cortisol result on day 3 is <50 nmol/L, the patient has shown appropriate suppression and Cushing’s syndrome can be ruled out.

- Patients with Cushing’s syndrome, from whatever cause, lose the normal negative feedback control by circulating glucocorticoids on ACTH release and thus exhibit detectable plasma ACTH and cortisol concentrations after dexamethasone administration.

- In patients who fail to suppress, a pre-test ACTH level of <5ng/L is highly suggestive of an adrenal cause of Cushing’s syndrome.

- Cortisol suppression >30% following the low dose dexamethasone suppression test correlates well with the response in the high dose dexamethasone suppression test and is therefore suggestive of Cushing’s disease.

#### References


High Dose Dexamethasone Suppression Test

CWS CODE: None – Please request tests separately

Principle
This test is used in patients who have Cushing’s syndrome established by screening, but with requirement for the aetiology to be further identified. The test works on the basis that in most situations the corticotroph tumour cells in Cushing’s disease retain some responsiveness to the negative feedback of glucocorticoids, whilst tumours ectopically secreting ACTH will not. However, the HDDST maybe abnormal in healthy people and normal in patients with Cushing’s syndrome and therefore may not be helpful in establishing the diagnosis. Indeed, for adults the pre-test probability of ACTH-dependent Cushing’s syndrome being secondary to pituitary dependent Cushing's disease is 85-90%. The HDDST correctly identifies 69% of adult patients as having Cushing’s disease. Since the diagnostic accuracy of this test in identifying Cushing’s disease is less than the pre-test probability of making this diagnosis, this test is now rarely used. As ectopic causes of Cushing’s syndrome are extremely rare in children, there is a very limited evidence base concerning the use of this test, although one group advocate the use of the low dose dexamethasone suppression test as an adequate alternative (with suppression of >30% being suggestive of Cushing’s disease).

Indication
- To differentiate pituitary-dependent and ectopic causes of Cushing’s syndrome.

Precautions
- False positive results may be obtained following the use of drugs that accelerate dexamethasone metabolism including phenobarbital, phenytoin, carbamazepine, rifampin, rifapentine, ethosuximide, diltiazem or cimetidine. If possible these should be stopped a few weeks prior to the test.
- Drugs that increase cortisol binding globulin (CBG) may also falsely elevate cortisol results including oestrogens.
- Dexamethasone clearance maybe reduced in patients with liver and/ or renal failure.
- Dexamethasone should be used cautiously in a child with diabetes mellitus with meticulous measurements of blood glucose during the period of the test.
- The child should not be on exogenous glucocorticoids during the test including steroid creams, inhalers and eye drops.

Side Effects
- No significant side effects

Preparation
- This test may be performed sequentially following the LDDST

Protocol

ACTH samples should be sent IMMEDIATELY to laboratory on ice for centrifugation and freezing

1. Day 1 - Take blood samples for cortisol and plasma ACTH at 0900h and 2400h
2. Days 2 and 3 - Starting at 0900h administer dexamethasone every 6 hours (i.e. 1500, 2100, 0300h) as follows:
   a. If the patient weighs more than 40 kg use a dose of 2 mg dexamethasone
   b. If the patient weighs less than 40 kg use a dose of 120 mcg/kg/day (divided into 4 daily doses)

   All doses must be adhered to for the test to be valid
3. Day 4 - Take blood sample for serum cortisol and plasma ACTH at 0900h, 6 hr after the last dose of dexamethasone.
Time Points:

<table>
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<tr>
<th>Day</th>
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<th>Procedure</th>
<th>Sample</th>
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<td>0900</td>
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<td>Blood for Cortisol/ ACTH</td>
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<td></td>
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<td>Blood for Cortisol/ ACTH</td>
</tr>
</tbody>
</table>

Samples

**ACTH**
2-3 mL blood in a 5 mL lithium heparin tube (orange top)

*Send IMMEDIATELY to laboratory on ice for centrifugation and freezing*

**Cortisol**
2 mL lithium heparin (orange top) or clotted blood (white top)

Record sample collection times and time of dexamethasone administration on the request form.

Interpretation

- Patients with pituitary-dependent hypercortisolism (Cushing’s disease) will usually show suppression of plasma cortisol to at least 50% of basal values. Those with ectopic ACTH secretion will not show any suppression of Cortisol. Please note that approximately 10% of patients with Cushing’s disease fail to suppress and approximately 10% of those with ectopic ACTH secretion will suppress.

References

CRH Test

CWS Test Name: None – Please request tests separately

Principle
CRH is normally released by the hypothalamus to stimulate ACTH release by the anterior pituitary. The administration of a CRH analogue (corticorelin) can therefore be used to assess the ability of the pituitary gland to secrete ACTH for the stimulation of cortisol production. Generally patients with pituitary ACTH deficiency have a decreased ACTH and cortisol response to CRH. Patients with hypothalamic disorders however have an exaggerated and prolonged plasma ACTH response and a subnormal cortisol response.

The CRH test may also be used in combination with dexamethasone suppression tests for the differential diagnosis of Cushing’s syndrome. CRH administration results in an excessive rise in plasma ACTH and serum cortisol in patients with pituitary Cushing’s disease, whilst this is rarely seen in patients with ectopic ACTH secretion. The CRH test can therefore be used in the differential diagnosis of Cushing’s syndrome to confirm whether the cause is pituitary-dependent or ectopic.

Indication
To differentiate between pituitary-dependent and ectopic causes of Cushing’s syndrome.

Precautions
- Imipramine may reduce the ACTH response

Side Effects
- Flushing of the face, neck and upper body, hypotension or a mild sensation of taste or smell may occur following administration of CRH.

Preparation
- The patient should be fasted overnight (for a minimum of 4 hours).
- The patient should remain supine throughout the test.
- If the patient is to also have a high dose dexamethasone suppression test, the CRH test should be performed first.

Protocol
1. Insert a reliable cannula and wait 30 minutes before proceeding with the test.
2. Take a blood sample for ACTH and cortisol 15 minutes after the insertion of the cannula.
3. 15 min later: **Administer CRH (corticorelin) i.v. at a dose of 1 mcg/kg body weight (to a maximum of 100 mcg) over 30 seconds.** Collect blood samples for ACTH and cortisol (t = 0).
4. Take further blood samples for ACTH and cortisol at 15, 30, 45, 60, 90 and 120 min post CRH administration.
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Time Points:

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<td>30</td>
<td>-</td>
<td>Blood for Cortisol/ ACTH</td>
</tr>
<tr>
<td>45</td>
<td>-</td>
<td>Blood for Cortisol/ ACTH</td>
</tr>
<tr>
<td>60</td>
<td>-</td>
<td>Blood for Cortisol/ ACTH</td>
</tr>
<tr>
<td>90</td>
<td>-</td>
<td>Blood for Cortisol/ ACTH</td>
</tr>
<tr>
<td>120</td>
<td>-</td>
<td>Blood for Cortisol/ ACTH</td>
</tr>
</tbody>
</table>

Samples

**ACTH** 2-3 mL blood in a 5 mL lithium heparin tube (orange top)

*Send IMMEDIATELY to laboratory on ice for centrifugation and freezing*

**Cortisol** 1 mL lithium heparin (orange top) or clotted blood (white top)

Interpretation

- A peak increment of serum cortisol >20% and plasma ACTH >50% suggests Cushing’s disease. The CRH test has a sensitivity of 86-93% and a specificity of 90-100% using these cut off values to discriminate Cushing’s disease from ectopic ACTH secretion.

- A rise in ACTH by 35% at 15 and 30 min compared to basal levels also suggests a pituitary source.

- The CRH test has been reported to show a high sensitivity in diagnosis of Cushing’s disease in pre-pubertal children.

- CRH is also used to aid bilateral petrosal sinus sampling. The diagnostic sensitivity of basal central/peripheral ACTH ratio >2 and >3 post CRH is 94%.

References

1. Nieman LK, Lacroix A, Martin KA. Corticotrophin-releasing hormone stimulation test. UpToDate April 2012
Cortisol Day Curve – Monitoring hydrocortisone replacement

CWS Test Name: None – Please request tests separately

Indication
- Patients with adrenal insufficiency require monitoring to ensure that they are receiving an adequate dose of hydrocortisone replacement therapy.

Precautions
- None

Preparation
- The patient is required to attend the ETC as a day case, generally arriving before taking their normal morning dose of hydrocortisone
- In this situation, the baseline blood sample should be taken before the morning dose of hydrocortisone
- Dependent on hospital admission, this protocol can be started at any time of day as long as it covers a number of hydrocortisone doses with sampling every 2 hours. The protocol indicated below is for guidance, but may be adapted.

Protocol
1. Insert a reliable cannula in order to collect blood samples at the time points indicated.
2. The time points of blood collection will depend upon the hydrocortisone treatment regimen of the patient. Blood samples for cortisol should be collected pre-dose and then 2 hourly, stopping with the next pre-dose blood sample. ACTH may also be measured every 4 hours if this is thought to be clinically useful. The table below is for guidance.
3. If it is felt there is clinical need to continue to monitor the adequacy of hydrocortisone replacement, this profile can be continued with blood samples for cortisol every 2 hours and for ACTH every 4 hours.

Time Points:

<table>
<thead>
<tr>
<th>Time</th>
<th>Time point</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>On patient arrival</td>
<td>Pre-dose</td>
<td>Blood for Cortisol/ACTH</td>
</tr>
<tr>
<td>08:00</td>
<td>Patient should take normal morning dose of hydrocortisone</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>2 hrs post dose</td>
<td>Blood for Cortisol</td>
</tr>
<tr>
<td>12:00</td>
<td>4 hrs post dose</td>
<td>Blood for Cortisol/ACTH</td>
</tr>
<tr>
<td>14:00</td>
<td>Pre-dose</td>
<td>Blood for Cortisol</td>
</tr>
<tr>
<td></td>
<td>Patient should take normal dose of hydrocortisone</td>
<td></td>
</tr>
</tbody>
</table>

Samples
- **Cortisol**: 1 mL lithium heparin (orange top) or clotted blood (white top)
- **ACTH**: 2-3 mL blood in a 5 mL lithium heparin tube (orange top)

Send IMMEDIATELY to laboratory on ice for centrifugation and freezing.
Cortisol Day Curve – Assessment of adrenal function

CWS Test Name: None – Please request tests separately

Indication
- Monitoring endogenous secretion of cortisol and ACTH may be rarely used in the assessment of adrenal function in order to further support the diagnostic work up.
- Patients with exogenous suppression of ACTH are evaluated for recovery of the hypothalamic-pituitary-adrenal axis by monitoring endogenous secretion of cortisol and ACTH during a period of time when patients have stopped taking corticosteroids.

Precautions
- None

Preparation
- For assessment of recovery of the hypothalamic-pituitary-adrenal axis steroid therapy should be stopped. All glucocorticoid therapy (other than dexamethasone or betamethasone) interferes with the assay of cortisol. If the patient is on prednisolone therapy, this must be discontinued for 24 hours prior to the test. If the patient is on a supra-physiological dose of hydrocortisone, this should be reduced to a physiological level (6 mcg/m²/day) prior to the test. Omit the dose the night before and on the morning of the test. However, the patient should take their usual dose of corticosteroid as soon as the test is completed.

Protocol
1. Insert a reliable cannula in order to collect blood samples at the time points indicated.
2. Blood samples for cortisol should be collected 2 hourly in order to assess the diurnal variation of secretion. ACTH samples should be collected every 4 hours. The table below is for guidance.
3. If it is felt there is clinical need to continue to monitor adrenal function this profile can be continued as indicated with blood samples for cortisol every 2 hours and for ACTH every 4 hours

Time Points:

<table>
<thead>
<tr>
<th>Time</th>
<th>Time point</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00 or on</td>
<td>Baseline</td>
<td>Blood for Cortisol/ACTH</td>
</tr>
<tr>
<td>patient arrival</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>2 hrs</td>
<td>Blood for Cortisol</td>
</tr>
<tr>
<td>12:00</td>
<td>4 hrs</td>
<td>Blood for Cortisol/ACTH</td>
</tr>
<tr>
<td>14:00</td>
<td>6 hrs</td>
<td>Blood for Cortisol</td>
</tr>
</tbody>
</table>

Samples
- **Cortisol**: 1 mL lithium heparin (orange top) or clotted blood (white top)
- **ACTH**: 2-3 mL blood in a 5 mL lithium heparin tube (orange top)

*Send IMMEDIATELY to laboratory on ice for centrifugation and freezing*
**Cortisol Day and Night Curve**

**CWS Test Name:** None – Please request tests separately

**Indication**
- Patients with congenital adrenal hyperplasia (CAH) require monitoring to ensure that they are receiving an adequate dose of hydrocortisone replacement therapy. The endocrine team at RMCH advocate a 24 hour cortisol curve for CAH patients. A 24 hour cortisol curve may also be appropriate for monitoring corticosteroid therapy for adrenal insufficiency.

**Precautions**
- None

**Preparation**
- The patient is required to attend the ETC overnight, continuing to take hydrocortisone as prescribed.

**Protocol**
1. Insert a reliable cannula in order to collect blood samples at the time points indicated
2. The time points of blood collection will depend upon the hydrocortisone treatment regimen of the patient. Blood samples for cortisol should be collected pre-dose and then 2 hourly during the day and 4 hourly overnight. In patients with CAH it may also be useful to collect blood samples for 17-α-hydroxyprogesterone at the same time points. Samples should be collected over a 24 hour period as indicated. The table below is for guidance.

**Protocol**
**Time Points: 17OHP is only required in patients with CAH**

<table>
<thead>
<tr>
<th>Time post CRH (min)</th>
<th>Time point</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:00</td>
<td>Patient arrival on ward, pre-dose</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td>18:00</td>
<td>Pre-dose sample</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td></td>
<td>Patient should take normal night time dose of hydrocortisone</td>
<td></td>
</tr>
<tr>
<td>22:00</td>
<td>4 hrs post dose</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td>2:00</td>
<td>8 hrs post dose</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td>6:00</td>
<td>12 hrs post dose</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td>8:00</td>
<td>Pre-dose</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td></td>
<td>Patient should take normal dose of hydrocortisone</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>2 hrs post dose</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td>12:00</td>
<td>4 hrs post dose</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td>14:00</td>
<td>Pre-dose</td>
<td>Blood for Cortisol, 17OHP</td>
</tr>
<tr>
<td></td>
<td>Patient should take normal dose of hydrocortisone</td>
<td></td>
</tr>
</tbody>
</table>

**Samples**
- **Cortisol** 1 mL lithium heparin (orange top) or clotted blood (white top)
- **17-OHP** 1 mL lithium heparin (orange top) or clotted blood (white top)
The diagnosis of GHD in childhood is a multi-faceted process requiring clinical and auxological assessment, combined with biochemical tests of the GH-insulin-like growth factor (IGF) axis and radiological evaluation. Diagnosis can prove extremely difficult due to the poor reproducibility, specificity and sensitivity of the non-physiological biochemical tests involved. GHD may present as an isolated problem or in combination with multiple pituitary hormone deficiency (MPHD).

Evaluation for GHD in short stature (defined as height ≥2 s.d. below the population mean) should not be initiated until other chronic, non-endocrine causes of growth failure (e.g. hypothyroidism, chronic systemic disease, Turner's syndrome, skeletal disorder) have been excluded. Due to the intrinsic diagnostic inaccuracy of any GH provocation test, correct selection of the child to be tested remains of upmost importance.

Criteria to initiate investigation for GHD include:
1. Severe short stature, defined as a height >3 s.d. below the population mean
2. Height >1.5 s.d. below the mid-parental height
3. Height >2 s.d. below the mean and a height velocity over 1 yr >1 s.d. below the mean for chronological age, or a decrease in height s.d. of >0.5 over 1 yr in children over 2 yrs of age.
4. In the absence of short stature, growth failure as suggested by:
   a. A height velocity >2 s.d. below the mean over 1 year
   b. A height velocity >1.5 s.d. below the mean sustained over 2 years
5. Signs indicative of an intracranial lesion
6. Signs of multiple pituitary hormone deficiency
7. Neonatal symptoms and signs of Growth hormone deficiency (e.g. in children with pituitary tumours, septo-optic dysplasia and neonatal hypoglycaemia)

The symptoms most commonly encountered are highlighted in italics.

Biochemical assessment of GHD
Random single GH estimations are rarely helpful in diagnosing or excluding GHD due to the pulsatile release of the hormone. Instead, a variety of provocation tests may be used, each following an overnight fast. A basic requirement is for diagnosis to be supported by at least 2 stimulation tests\(^4\), and this requirement also been recommended by NICE\(^2\). The stimulation tests in current use are not ideal due to poor reproducibility and dependence on a number of factors such as body composition and pubertal status.

A peak plasma GH concentration of ≥7 µg/L indicates a normal response to the test and no further investigations are required. A peak plasma GH concentration of <5 µg/L is diagnostic of growth hormone deficiency. A peak plasma GH concentration of 5 – 7 µg/L may still be indicative of GH deficiency and requires further investigation.

In the transition from childhood to adulthood a peak GH concentration of <5 µg/L is used to determine patients requiring treatment. In adults a peak GH concentration of <3 µg/L is used to diagnose GHD.

The cut off levels used are arbitrary values as even normal children can have low peak GH values. The cut off value may be used independently of the type of test and assay methodology involved. This does, however, make interpretation difficult as it is well known that there is not only considerable inter and intra-individual variation with these tests, but the GH response also varies depending on the assay and stimulus used.

Measurement of IGF-1 and IGFBP-3 are reflective of the circulating level of GH but have relatively small variation during the course of the day and as such can be used to aid discrimination between normal and abnormal GH release. For IGF-1 ranges, standardized for age and sex (see table on page 20), values below the reference range for age support an abnormality in the GH axis if other causes of low IGF (e.g.
malnutrition) have been excluded. Nevertheless in GHD values of IGF-1 and IGFBP-3 within the normal range can occur.

All GH provocation tests should be performed on a dedicated clinical investigation unit. On the Elective Treatment Centre (Ward 76) at RMCH, Arginine and Glucagon are the main provocation tests used.

IGF-1 Reference Ranges according to age, gender and tanner stage using the IDS iSYS IGF-1 assay.

<table>
<thead>
<tr>
<th>Male Reference Range</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td>IGF-I (ng/mL)</td>
</tr>
<tr>
<td>&lt; 1 Year</td>
<td>13 - 138</td>
</tr>
<tr>
<td>1</td>
<td>18 - 176</td>
</tr>
<tr>
<td>2</td>
<td>23 - 212</td>
</tr>
<tr>
<td>3</td>
<td>28 - 247</td>
</tr>
<tr>
<td>4</td>
<td>34 - 282</td>
</tr>
<tr>
<td>5</td>
<td>40 - 316</td>
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<tr>
<td>6</td>
<td>46 - 349</td>
</tr>
<tr>
<td>7</td>
<td>53 - 382</td>
</tr>
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<td>8</td>
<td>60 - 414</td>
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<tr>
<td>9</td>
<td>68 - 443</td>
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<tr>
<td>10</td>
<td>75 - 469</td>
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<tr>
<td>11</td>
<td>83 - 490</td>
</tr>
<tr>
<td>12</td>
<td>90 - 505</td>
</tr>
<tr>
<td>13</td>
<td>96 - 514</td>
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<tr>
<td>14</td>
<td>101 - 516</td>
</tr>
<tr>
<td>15</td>
<td>104 - 512</td>
</tr>
<tr>
<td>16</td>
<td>107 - 502</td>
</tr>
<tr>
<td>17</td>
<td>109 - 488</td>
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<tr>
<td>18 - 20</td>
<td>109 - 472</td>
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<td>21 - 25</td>
<td>97 - 411</td>
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<td>84 - 313</td>
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<td>77 - 250</td>
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<td>36 - 40</td>
<td>72 - 225</td>
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<td>41 - 45</td>
<td>65 - 210</td>
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<tr>
<td>46 - 50</td>
<td>59 - 200</td>
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<tr>
<td>51 - 60</td>
<td>48 - 197</td>
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<tr>
<td>61 - 70</td>
<td>43 - 195</td>
</tr>
<tr>
<td>71 - 80</td>
<td>38 - 194</td>
</tr>
<tr>
<td>&gt; 80</td>
<td>35 - 183</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Female Reference range</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td>IGF-I (ng/mL)</td>
</tr>
<tr>
<td>&lt; 1 Year</td>
<td>16 - 143</td>
</tr>
<tr>
<td>1</td>
<td>19 - 160</td>
</tr>
<tr>
<td>2</td>
<td>22 - 178</td>
</tr>
<tr>
<td>3</td>
<td>25 - 198</td>
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<td>4</td>
<td>29 - 219</td>
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<td>34 - 244</td>
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<tr>
<td>6</td>
<td>39 - 271</td>
</tr>
<tr>
<td>7</td>
<td>45 - 302</td>
</tr>
<tr>
<td>8</td>
<td>52 - 336</td>
</tr>
<tr>
<td>9</td>
<td>59 - 371</td>
</tr>
<tr>
<td>10</td>
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<td>12</td>
<td>82 - 467</td>
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<td>13</td>
<td>89 - 488</td>
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<tr>
<td>14</td>
<td>94 - 501</td>
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<td>15</td>
<td>98 - 505</td>
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<tr>
<td>16</td>
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<td>17</td>
<td>102 - 493</td>
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<td>18 - 20</td>
<td>103 - 478</td>
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<tr>
<td>21 - 25</td>
<td>86 - 419</td>
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<td>26 - 30</td>
<td>74 - 319</td>
</tr>
<tr>
<td>31 - 35</td>
<td>69 - 260</td>
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<tr>
<td>36 - 40</td>
<td>65 - 236</td>
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<td>41 - 45</td>
<td>59 - 215</td>
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<td>46 - 50</td>
<td>54 - 199</td>
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<tr>
<td>51 - 60</td>
<td>43 - 187</td>
</tr>
<tr>
<td>61 - 70</td>
<td>37 - 170</td>
</tr>
<tr>
<td>71 - 80</td>
<td>34 - 167</td>
</tr>
<tr>
<td>&gt; 80</td>
<td>31 - 176</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Tanner Stage</th>
<th>IGF-I (ng/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5%</td>
<td>25%</td>
</tr>
<tr>
<td>Male</td>
<td>I</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>236</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>218</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>229</td>
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<tr>
<td>Female</td>
<td>I</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>249</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>238</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>187</td>
</tr>
</tbody>
</table>
**Sex Steroid Priming**

In pre- and peri-pubertal children who have a sub-normal response to provocative testing, sex steroid priming may increase the response to that seen in late puberty and should therefore be considered. Sex steroid priming can provide an adequate response to stimulation in healthy pre-pubertal children, and is proposed to reduce the number of false positive test results. As a guideline, priming may be indicated in girls above 8 years, and boys above 9 years of age. There is currently no consensus regarding sex steroid priming prior to GH provocation testing\(^3\), however the following protocol has been agreed by endocrinologists at RMCH. GH provocation tests following estradiol priming have been reported to have the highest diagnostic accuracy\(^3\).

**GIRLS:**
Over 8 years of age, with no signs of puberty.
Give 10 - 20 mcg oral Ethinyl Estradiol in the evening daily for 3 days.
Commence test on 4th day.

**BOYS:**
Over 9 years of age, with no signs of puberty.
Give 10 - 20 mcg oral Ethinyl Estradiol in the evening daily for 3 days.
Commence test on 4th day.

**References:**
**Arginine Stimulation Test**

**CWS Test Name:** ARGinine TEST

**Principle**
Arginine is used as a provocative agent during a stimulation test in the diagnosis of children with suboptimal growth. Arginine reduces somatostatin release and stimulates α-adrenergic receptors resulting in GHRH release. The test has a sensitivity of 75% with a specificity of 85% using a diagnostic cut-off of 7 μg/L. This can be increased to a sensitivity of 100% and specificity of 98% if clinical evidence of GHD is also present.  

**Indication**
- See *Diagnosis of Growth Hormone Deficiency*

**Precautions**
- None

**Side Effects**
- Arginine may cause nausea and some irritation at the infusion site, although this is limited by the infusion being carried out over a 30 minute time period.
- Arginine may also rarely cause anaphylaxis.
- In children with suspected hypopituitarism prolonged fasting may induce hypoglycaemia. Blood glucose should be checked by POCT in these patients whenever a sample is taken.

**Preparation**
- Thyroid function should be normal; this must be ascertained before commencing the test.
- GH should be stopped for at least 4 weeks prior to the test.
- Sex steroid priming may be necessary, see *Diagnosis of Growth Hormone Deficiency*
- Patients should have water only for 8 hours prior to the test.
- For very young children, particularly those <1 year, a smaller duration of fast, possibly 4 hours should be adequate. This should be discussed with the consultant endocrinologist.

**Protocol**
1. Insert an indwelling cannula and take a basal blood sample (t=-30). Cannulation may cause growth hormone to rise; therefore the patient should rest for 30 min before the test is commenced.
2. Take a blood sample before commencing the infusion of arginine (t = 0). *Infuse arginine monohydrochloride (10% solution in 0.9% sodium chloride) i.v. over 30 min in a dose of 0.5g/kg body weight up to a maximum of 30g.*
3. Take blood samples for growth hormone 15, 30, 45, 60, 90 and 120 min after the start of the arginine infusion. At each time point also check the blood glucose of the patient using a blood glucose meter.
### Time Points:

<table>
<thead>
<tr>
<th>Time post arginine infusion (min)</th>
<th>Procedure</th>
<th>Blood Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>0</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>15</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>30</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>45</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>60</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>90</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>120</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
</tbody>
</table>

**Samples**

**Growth Hormone**  
1 mL clotted blood (white top)

**Interpretation**

- A peak plasma GH concentration of $\geq 7\,\mu g/L$ indicates a normal response to the test and no further investigations are required.
- A peak plasma GH concentration of $<5\,\mu g/L$ is diagnostic of growth hormone deficiency but requires a second GH provocation test to confirm.
- A peak plasma GH concentration of $5 - 7\,\mu g/L$, may still be indicative of GH deficiency and requires further investigation.
- In adults, a peak plasma GH concentration of $<3\,\mu g/L$ is diagnostic of growth hormone deficiency.
- The percentage of children who are not GH deficient and who show a normal response to this test varies from 45 – 93%. Generally 20% of normal children fail to respond to a formal test and this is the reason for doing 2 tests before proceeding to GH therapy. For example, 71% of normal individuals will respond to both insulin tolerance and arginine stimulation tests. However, the others will respond to at least one test: 13% to insulin, 16% to arginine.

**References**

Glucagon Stimulation Test for Growth Hormone

CWS Test Name: G GON-HGH

Principle
This test is commonly used for the evaluation of growth hormone deficiency (GHD). Glucagon causes blood glucose to increase leading to insulin release and therefore indirectly stimulating GH and ACTH release through provocation of the hypothalamic-pituitary axis.

Indication
- See Diagnosis of Growth Hormone Deficiency

Precautions
- The test should not be performed on a patient with phaeochromocytoma or insulinoma as it may provoke an attack.
- The test should not be carried out following starvation of >48 hours or in the presence of a glycogen storage disease. The inability to mobilise glycogen may result in hypoglycaemia.
- The test should not be carried out in patients with severe hypocortisolaemia (9 am level <100 nmol/L)
- Thyroid function must be normal as thyroxine deficiency may reduce the GH response.

Side Effects
- Nausea and abdominal pain are common (30%) and patients may rarely vomit.

Preparation
- Thyroid function and cortisol must be checked to rule out panhypopituitarism
- GH should be stopped for at least 4 weeks prior to the test.
- Patients must fast for 8 hours prior to the test (water only is allowed).
- Sex steroid priming may be necessary, see Diagnosis of Growth Hormone Deficiency

Protocol
Children can become hypoglycaemic after glucagon administration, usually 90 – 120 minutes post dose. Children <8 yrs of age are at particular risk. Check glucose levels (by glucose meter) at the time of every sample. Check that the child is responsive at the time of every sample. If they do not respond then follow instructions for the emergency management of hypoglycaemia.

1. Insert an indwelling 22 gauge, blue, cannula and take a basal blood sample (t = -30). Wait 30 minutes before taking the baseline (t = 0) sample for growth hormone as cannulation may cause GH to rise.

2. Check glucose level by meter.
   - If glucose < 2.6 mmol/L do not administer glucagon.
   - If glucose level > 2.6 mmol/L then administer glucagon i.m. using a dose of 30 µg/kg of body weight up to a maximum dose of 1 mg.

3. Take further blood samples for growth hormone at 60, 90, 120, 150 and 180 min post glucagon administration.

4. Observe for signs of hypoglycaemia throughout the test and record in patient’s notes

5. Remember to check the child’s glucose level by meter and the responsiveness at every sample.

6. A sweet drink and a full meal must be eaten and tolerated after the test and the child should be observed for 1 hour after the test. Blood glucose (by meter) must be >4 mmol/L before discharge.
Endocrine Dynamic Function Test Protocols for use in Neonates and Children

Time Points:

<table>
<thead>
<tr>
<th>Time post glucagon (min)</th>
<th>Procedure</th>
<th>Blood Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>0</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>60</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>90</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
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<tr>
<td>120</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>150</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
<tr>
<td>180</td>
<td>Check blood glucose using meter</td>
<td>Growth hormone</td>
</tr>
</tbody>
</table>

Samples

*Growth Hormone* 1 mL clotted blood (white top)

Interpretation

- A peak plasma GH concentration of $\geq 7$ µg/L indicates a normal response to the test and no further investigations are required.
- A peak plasma GH concentration of $<5$ µg/L is diagnostic of growth hormone deficiency but requires a second GH provocation test to confirm the diagnosis.
- A peak plasma GH concentration of 5 – 7 µg/L, may still be indicative of GH deficiency and requires further investigation.
- In adults, a peak plasma GH concentration of $<3$ µg/L is diagnostic of growth hormone deficiency.
- Peak GH responses are also highly dependent on both short term nutritional status and on BMI – higher peak GH levels after short term fasting and in those with lower BMI.

References

1. Basildon and Thurlow University Hospitals NHS Foundation Trust Clinical Biochemistry Department paediatric department Glucagon Stimulation test Paediatric protocol
Glucagon Stimulation Test for Cortisol & Growth Hormone

**CWS Test Name:** G GON-CORTIS

**Principle**
This test can be used as an alternative to the insulin-induced hypoglycaemia test in the evaluation of central adrenal insufficiency. Glucagon requires endogenous ACTH to cause cortisol secretion.

**Indication**
- To identify secondary adrenal insufficiency or combined ACTH/GH deficiency

**Precautions**
- The test should not be performed on a patient with phaeochromocytoma or insulinoma as it may provoke an attack.
- The test should not be carried out following starvation of >48 hours or in the presence of a glycogen storage disease. The inability to mobilise glycogen may result in hypoglycaemia.
- The test should not be carried out in patients with severe hypocortisolaeemia (9 am level <100 nmol/L).
- Thyroid function must be normal as thyroxine deficiency may reduce the GH and cortisol response.

**Side Effects**
- Nausea and abdominal pain are common (30%) and patients may rarely vomit.

**Preparation**
- Thyroid function and cortisol must be checked to rule out panhypopituitarism.
- GH should be stopped for at least 2 weeks prior to the test.
- All glucocorticoid therapy (other than dexamethasone or betamethasone) interferes with the assay of cortisol. If the patient is on prednisolone therapy, this must be discontinued for 24 hours prior to the test. If the patient is on a supra-physiological dose of hydrocortisone, this should be reduced to a physiological level (6 mcg/m^2/day) prior to the test. Omit the dose the night before and on the morning of the test. If the paediatric endocrine consultant is very anxious about the degree of adrenal insufficiency then omit only the morning hydrocortisone dose. However, the patient should take their usual dose of corticosteroid as soon as the test is completed.
- Patients must fast for 8 hours prior to the test (water only is allowed).
- Sex steroid priming may be necessary, see Diagnosis of Growth Hormone Deficiency

**Protocol**
*Children can become hypoglycaemic after glucagon administration, usually 90 – 120 minutes post dose. Children <8 yrs of age are at particular risk. Check glucose levels (by glucose meter) at the time of every sample. Check that the child is responsive at the time of every sample. If they do not respond then follow instructions for the emergency management of hypoglycaemia.*

1. Insert an indwelling 22 gauge, blue, cannula and wait 30 minutes before taking the baseline (t=0) sample for cortisol and growth hormone.
2. Check glucose level by meter.
   - If glucose <2.6 mmol/L do not administer glucagon.
   - If glucose level >2.6 mmol/L then administer glucagon i.m. using a dose of 30 µg/kg of body weight up to a maximum dose of 1 mg.
3. Take further blood samples for cortisol at 30, 60, 90, 120, 150 and 180 min post glucagon administration.
4. Observe for signs of hypoglycaemia throughout the test and record in patient’s notes.
5. Remember to check the child’s glucose level by meter and the responsiveness at every sample.
6. A sweet drink and a full meal must be eaten and tolerated after the test and the child should be observed for 1 hour after the test. Blood glucose (by meter) must be >4 mmol/L before discharge.
**Endocrine Dynamic Function Test Protocols for use in Neonates and Children**

**Time Points:**

<table>
<thead>
<tr>
<th>Time post glucagon (min)</th>
<th>Procedure</th>
<th>Blood Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Check blood glucose using meter</td>
<td>Cortisol, Growth Hormone</td>
</tr>
<tr>
<td>30</td>
<td>Check blood glucose using meter</td>
<td>Cortisol, Growth Hormone</td>
</tr>
<tr>
<td>60</td>
<td>Check blood glucose using meter</td>
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<tr>
<td>90</td>
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</tr>
<tr>
<td>120</td>
<td>Check blood glucose using meter</td>
<td>Cortisol, Growth Hormone</td>
</tr>
<tr>
<td>150</td>
<td>Check blood glucose using meter</td>
<td>Cortisol, Growth Hormone</td>
</tr>
<tr>
<td>180</td>
<td>Check blood glucose using meter</td>
<td>Cortisol, Growth Hormone</td>
</tr>
</tbody>
</table>

**Samples**

**Cortisol**

1 mL lithium heparin (orange top) or clotted blood (white top)

**Interpretation**

- A peak plasma cortisol concentration of ≥550 nmol/L is indicative of a normal response and normal adrenal function.
- A peak plasma GH concentration of ≥7 µg/L indicates a normal response to the test and no further investigations are required.
- A peak plasma GH concentration of <5 µg/L is diagnostic of growth hormone deficiency but requires a second GH provocation test to confirm the diagnosis.
- A peak plasma GH concentration of 5 – 7 µg/L may still be indicative of GH deficiency and requires further investigation.
- In adults, a peak plasma GH concentration of <3 µg/L is diagnostic of growth hormone deficiency.
- Peak GH responses are also highly dependent on both short term nutritional status and on BMI – higher peak GH levels after short term fasting and in those with lower BMI.

**References**

1. Basildon and Thurlow University Hospitals NHS Foundation Trust Clinical Biochemistry Department paediatric department Glucagon Stimulation test Paediatric protocol
Insulin Tolerance Test

This test is potentially dangerous and is not carried out routinely at RMCH. Consult with the paediatric endocrine team at RMCH if you are considering undertaking this test. It should only be carried out in specialist centres by experienced staff.

CWS Test Name: INSULIN TOLERANCE TEST

Principle
The insulin tolerance test is the gold standard test for assessing the integrity of the hypothalamo-pituitary-adrenal axis. Stress, in this case hypoglycaemia, leads to the secretion of the hypothalamic hormones growth hormone releasing hormone (GHRH) and corticotrophin releasing hormone (CRH) which in turn stimulate the pituitary to produce GH and ACTH. ACTH production is assessed by the measurement of adrenal cortisol production. This test is dangerous as it relies on the induction of symptomatic hypoglycaemia which must be treated immediately if the symptoms become severe.

Indication
- This test is not routinely used at RMCH, although it is considered the gold standard test to assess the integrity of the hypothalamo-pituitary-adrenal axis. We are most likely to use the ITT when retesting a young person for the presence of persistent GH deficiency at the end of growth. The test may also be required for some research protocols.

Precautions
- This test should not be carried out in a child with a history of epilepsy or cardiac arrhythmias.
- The test should be used with particular caution in young children as the symptoms of hypoglycaemia may be difficult to detect.
- This test should not be carried out on patients with severe panhypopituitarism or hypoadrenalism.
- This test should not be carried out in a patient with a glycogen storage disorder.
- A doctor must be present throughout this test with the patient being closely monitored for symptoms of hypoglycaemia which may require treatment.

Side Effects
- Sweating
- Palpitations
- Impaired or loss of consciousness

Preparation
- The patient must be fasted overnight (4 hours for infants), although drinks of water are allowed
- Ensure that glucose (10% dextrose) and hydrocortisone are available for i.v. injection if necessary
- A glucose drink must be available. This may be ~40g dextrose powder (4 heaped teaspoons) dissolved in approximately half a glass of squash, or standard lucozade
- Child must remain on the ward and eat for at least an hour after the test before the cannula is removed and the patient discharged

Protocol

Children can become severely hypoglycaemic after insulin administration. Check glucose levels (by glucose meter) at the time of every sample and observe the child continuously for symptoms of severe hypoglycaemia. Check that the child is responsive at the time of every sample. If they do not respond then follow instructions for the emergency management of hypoglycaemia.

1. Start the test between 0800h and 0900h. Weigh the patient and insert an indwelling cannula and take a basal blood sample (t = -30) for glucose, growth hormone and cortisol. Wait 30 minutes before taking the baseline (t = 0) sample for glucose, growth hormone and cortisol as cannulation may cause GH to rise. The patient should be resting throughout the test.

2. Check glucose level by meter.
   - If glucose <3.5 mmol/L do not administer insulin.
   - If glucose level 3.5 – 4.5 mmol/L then administer half the dose of insulin
   - If glucose > 4.5 mmol/L then continue with the test as indicated
3. Dilute soluble insulin (Actrapid) with normal saline to give a solution containing 1 unit per ml. **Give an i.v. dose of 0.1 units per kg body weight**

This dose should be reduced to 0.05 units per kg in patients who might be unduly sensitive to insulin, such as patients with suspected hypopituitarism, severe malnutrition, or those with a baseline blood glucose between 3.5 and 4.5 mmol/L.

4. Monitor blood glucose closely until adequate hypoglycaemia has been established (<2.2 mmol/L) or the child shows signs of hypoglycaemia (e.g. sweating or drowsiness). Administer glucose drink of ~40 g dextrose powder (4 heaped teaspoons) dissolved in approximately half a glass of squash, or standard lucozade. If there are more severe symptoms of hypoglycaemia (e.g. impaired consciousness), i.v. glucose may be required.

5. Take further blood samples for glucose, growth hormone and cortisol at 15, 30, 60 and 90 min post insulin administration

6. Remember to check the child’s glucose level by meter and the responsiveness at every sample.

<table>
<thead>
<tr>
<th>Time post insulin (min)</th>
<th>Procedure</th>
<th>Blood Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td>Check blood glucose using meter</td>
<td>Glucose, Growth hormone &amp; Cortisol</td>
</tr>
<tr>
<td>0</td>
<td>Check blood glucose using meter</td>
<td>Glucose, Growth hormone &amp; Cortisol</td>
</tr>
<tr>
<td>15</td>
<td>Check blood glucose using meter</td>
<td>Glucose, Growth hormone &amp; Cortisol</td>
</tr>
<tr>
<td>30</td>
<td>Check blood glucose using meter</td>
<td>Glucose, Growth hormone &amp; Cortisol</td>
</tr>
<tr>
<td>60</td>
<td>Check blood glucose using meter</td>
<td>Glucose, Growth hormone &amp; Cortisol</td>
</tr>
<tr>
<td>90</td>
<td>Check blood glucose using meter</td>
<td>Glucose, Growth hormone &amp; Cortisol</td>
</tr>
</tbody>
</table>

**Samples**

**Growth Hormone**

1 mL clotted blood (white top)

**Cortisol**

1 mL lithium heparin (orange top) or clotted blood (white top)

**Glucose**

1 mL venous blood in a fluoride oxalate tube (yellow top)

**Management of hypoglycaemia**

- If symptomatic, give glucose (3 mL/kg of i.v. 10% Dextrose) **INFORM DOCTOR**
- Give feed if able to tolerate, if not intravenous maintenance fluids, 10% dextrose + saline (e.g. 10% dextrose/0.45% saline)
- Recheck finger prick BG every 15 min until glucose >4.0mol/L
- If BG remains low consider further bolus and increase dextrose concentration/ fluid rate. Consider hydrocortisone bolus.
- CONTACT ENDOCRINE CONSULTANT ON CALL IF ANY CONCERNS
**Interpretation**

Interpretation is only possible if adequate hypoglycaemia (plasma glucose <2.2 mmol/L) has been achieved.

If the *laboratory* plasma glucose falls to 2.2 mmol/L or less, the imposed stress should be sufficient to stimulate a plasma GH concentration exceeding 7 µg/L.

Hypoglycaemia of this magnitude should also cause an increase in the plasma cortisol to concentrations exceeding 550 nmol/L.

**References**

1. Managed clinical network of Scottish Paediatric Endocrine Group (SPEG MCN) Dynamic function test handbook for Clinicians January 2012
**Combined Test of Anterior Pituitary Function (1) - Arginine, TRH, GnRH, Synacthen**

**CWS Test Name:** None – Please request tests separately

**Principle**
Simultaneous administration of GH stimulants and hypothalamic releasing hormones GnRH and TRH does not alter the hormonal response from that seen during a specific single provocation test. When multiple pituitary hormone deficiencies are suspected, it is practical and economical to carry out as many combined tests as possible.

**Indication**
- Investigation of known/suspected multiple pituitary hormone disease

**Precautions**
- The GnRH test cannot be performed if the child has been primed with sex steroid to stimulate GH response

**Side Effects**
- Arginine may cause nausea and some irritation at the infusion site, although this is limited by the infusion over a 30 minute time period.
- Arginine may also rarely cause anaphylaxis
- In children with suspected hypopituitarism prolonged fasting may induce hypoglycaemia. Blood glucose should be checked by POCT in these patients whenever a sample is taken.
- TRH administration can give patients the desire to urinate. It is therefore advisable to ask older children to empty their bladder before commencing the test.

**Preparation**
- Patients should have water only for 8 hours prior to the test.

**Protocol**
1. Insert an indwelling 22 gauge, blue cannula. Cannulation may cause growth hormone to rise; therefore the patient should rest for 30 min before the test is commenced. Take blood samples for growth hormone and U&E (BASAL, t = -30).
2. Infuse the arginine (10% solution) i.v. over 30 minutes in a dose of 0.5 g/kg up to a maximum of 30g. When the infusion is complete, flush through with saline.
3. Immediately following the arginine infusion (t = 0 min), check the patient’s blood glucose level using a meter. Take blood samples for GH, cortisol, prolactin, TSH, FT4, LH, FSH, testosterone (boys) and oestradiol (girls). 4 x 2 mL samples are required.
4. TRH, GnRH and synacthen are all given i.v. following the arginine infusion using the following doses:
   - **Thyroidiophin Releasing Hormone**
     TRH 5 mcg/kg (to a maximum of 200 mcg) injected slowly i.v. over 2 min.
   - **Gonadotrophin Releasing Hormone**
     Give a bolus of GnRH i.v. in a dose of 100 mcg. Children <1 year should be given a dose of 2.5 mcg/kg.
   - **Synacthen**
     Give Synacthen as an i.v. bolus
     For children 1- 12 months use a dose of 125 mcg
     For children > 1 yr use a dose of 250 mcg

**N.B.** For the combined TRH/GnRH/Synacthen omit the first part of the schedule relating to Arginine.
<table>
<thead>
<tr>
<th>Time Points and samples:</th>
<th>Arginine</th>
<th>TRH</th>
<th>GnRH</th>
<th>Synacthen</th>
<th>Extra Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time (min) post infusions</strong></td>
<td><strong>Blood sample</strong></td>
<td><strong>GH</strong></td>
<td><strong>Blood glucose</strong></td>
<td><strong>TSH</strong></td>
<td><strong>LH/FSH</strong></td>
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<tr>
<td>-30</td>
<td>2 mL Clotted 1 mL LiHep 1mL EDTA</td>
<td>+</td>
<td>+</td>
<td></td>
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</tr>
<tr>
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<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>30</td>
<td>2 mL Clotted</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
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<td>90</td>
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<tr>
<td>120</td>
<td>2 mL Clotted</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Samples**
- **Hormones**: 2 mL (minimum) clotted blood (white top)
- **U&E**: 1 mL lithium heparin blood (orange top)

Only one clotted blood is required for each of the times except for the baseline samples. It is, however, essential that each sample has a full 2 mL to ensure that there is sufficient blood volume for all tests.

One Biochemistry request form is needed for each hormone measured. Please indicate the time of the sample on both the specimen tube and the request form.

**Interpretation**
As for individual stimulation tests.

**References**
**Combined Test of Anterior Pituitary Function (2) - Glucagon, TRH, GnRH**

**CWS Test Name:** None – Please request tests separately

**Principle**
Simultaneous administration of GH stimulants and hypothalamic releasing hormones GnRH and TRH does not alter the hormonal response from that seen during a specific single provocation test. When multiple pituitary hormone deficiencies are suspected, it is practical and economical to carry out as many combined tests as possible.

**Indication**
- Investigation of known/suspected multiple pituitary hormone disease

**Precautions**
- The GnRH test cannot be performed if the child has been primed with sex steroid to stimulate GH response.
- The test should not be performed on a patient with phaeochromocytoma or insulinoma as it may provoke an attack.
- The test should not be carried out following starvation of >48 hours or in the presence of a glycogen storage diseases. The inability to mobilise glycogen may result in hypoglycaemia.
- The test should not be carried out in patients with severe hypocortisolaemia (9.00am level <100 nmol/L).
- Thyroid function must be normal as thyroxine deficiency may reduce the GH and cortisol response.

**Side Effects**
- Glucagon can commonly result in nausea and abdominal pain (30%) and patients may rarely vomit.
- In children with suspected hypopituitarism prolonged fasting may induce hypoglycaemia. Blood glucose should be checked by POCT in these patients whenever a sample is taken.
- Asthmatic patients should be carefully monitored.
- TRH administration can give patients the desire to urinate. It is therefore advisable to ask older children to empty their bladder before commencing the test.

**Preparation**
- Patients should have water only for 8 hours prior to the test.

**Protocol**
1. Insert an indwelling 22 gauge, blue cannula and take a blood sample for growth hormone and U&E (t = -30). Cannulation may cause growth hormone to rise; therefore the patient should rest for 30 min before the test is commenced.

2. Take blood samples for growth hormone, cortisol, prolactin, TSH, FT4, LH, FSH, testosterone (boys) or oestradiol (girls; BASAL, t = 0). Check the patient's blood glucose level using a meter.

3. **Infusions and Injections**
   - **Glucagon**
     Glucagon is administered i.m. using a dose of 30 µg/kg of body weight up to a maximum of 1 mg.

   - **Thyrotrophin Releasing Hormone**
     TRH 5 mcg/kg (to a maximum of 200 mcg) injected slowly i.v. over 2 min.

   - **Gonadotrophin Releasing Hormone**
     Give a bolus of GnRH i.v. in a dose of 100 mcg. Children <1 year should be given a dose of 2.5 mcg/kg.
### Time Points and samples:

<table>
<thead>
<tr>
<th>Time (min) post infusions</th>
<th>Blood sample</th>
<th>Glucagon</th>
<th>TRH</th>
<th>GnRH</th>
<th>Synacthen</th>
<th>Extra Tests</th>
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</thead>
<tbody>
<tr>
<td>-30</td>
<td>2 mL Clotted</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>U&amp;E</td>
</tr>
<tr>
<td></td>
<td>1 mL LiHep</td>
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<td></td>
<td></td>
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<td>1mL EDTA</td>
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</tr>
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<td>0</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>Prolactin, fT4, LH, FSH, Testosterone or Oestradiol</td>
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<td>2 x 2 mL Cotted</td>
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<td>+</td>
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<td>90</td>
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<td>+</td>
<td></td>
<td></td>
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<td>120</td>
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<td>2 mL Cotted</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Samples**

- **Hormones**
  - 2 mL (minimum) clotted blood (white top)
- **U&E**
  - 1 mL lithium heparin blood (orange top)

Only one clotted blood is required for each of the times except for the baseline samples, and at 60 min when 2 samples are required. It is, however, essential that each sample has a full 2 mL to ensure that there is sufficient blood volume for all tests.

One Biochemistry request form is needed for each hormone measured. Please indicate the time of the sample on both the specimen tube and the request form.

**Interpretation**

As for individual stimulation tests.

**References**

Glucose Suppression Test for Growth Hormone

CWS Test Name: GH SUPP TEST

Principle
Acromegaly in adults and gigantism in children are relatively rare diseases that are caused by persistent growth hormone (GH) hypersecretion. The estimated prevalence of acromegaly in adults is 60 cases per million with 3-4 new cases per million per year. In gigantism in children, the disease is diagnosed prior to epiphyseal fusion, leading to excessive tall stature. After completion of growth, the clinical symptoms become more similar to those in acromegalic adults like coarse facial features, acral changes, hyperhydrosis, headaches and visceromegaly. GH secretion is part of the counter-regulatory defence against hypoglycaemia and physiological GH secretion is inhibited by hyperglycaemia. In acromegaly, GH secretion is autonomous and does not suppress and may paradoxically rise with hyperglycaemia.

Indication
This test is used to investigate clinical suspicion of acromegaly or gigantism. Baseline GH values cannot be used to exclude acromegaly since elevated GH may occur with stress and low values are seen in up to 8% of acromegalic patients who are subsequently identified by the failure of GH to suppress during a GTT.

Precautions
This test is unnecessary in diabetics who have already shown GH suppression in the presence of hyperglycaemia.

Side Effects
Some subjects feel nauseated and may have vaso-vagal symptoms during this test.

Preparation
The diet over the preceding 3 days should contain adequate carbohydrate (approx 60% of calories).
- The patient should be fasted overnight for 10 to 14 hours (water only allowed) and should rest throughout the test.
- Physical exercise is not allowed in the morning prior to and/or during the test.
- The test should be performed in the morning.

Protocol
1. Prepare the glucose load as ONE of the following:
   - POLYCAL® (Nutricia Clinical) liquid. POLYCAL contains 0.66g anhydrous glucose per mL (or 1.51 mL contains 1g anhydrous glucose). The dose of POLYCAL must be adjusted for the weight of the child at a dose of 2.64 mL POLYCAL/kg body weight (to a maximum of 113 mL POLYCAL, equivalent to a 75g glucose load).
   OR
   - Anhydrous glucose. Anhydrous glucose can be used at a dose of 1.75 g/kg body weight to a maximum of 75g diluted in 200 mL water.
   OR
   - Lucozade Energy Original. Whilst Lucozade can be used, there are many different formulations available. Great care must be taken to ensure it is the correct formulation of Lucozade Energy Original; even a different flavour can change the sugar content (should be 70 kcal/100 mL). Lucozade should be given at a dose of 9.57 mL/kg body weight to a maximum of 410 mL.
   N.B. Lucozade is not an advised glucose challenge as the sodium in the drink may influence the rate of glucose uptake by the Na/glucose co-transporters.

2. Insert a reliable cannula and take a blood sample for growth hormone (t = -30). Wait for 30 min as cannulation may cause growth hormone to rise. Take a basal sample for glucose and growth hormone (t = 0).

3. The child should drink the glucose load over a period of about 5 min. Note the time the glucose load is given on the request form.
4. Take further blood samples for glucose and growth hormone 30, 60, 90, 120 and 180 min post administration of the glucose drink.

**Time Points:**

<table>
<thead>
<tr>
<th>Time post glucose drink (min)</th>
<th>Procedure</th>
<th>Blood Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td>-</td>
<td>Growth hormone, glucose</td>
</tr>
<tr>
<td>0</td>
<td>Drink glucose load</td>
<td>Growth hormone, glucose</td>
</tr>
<tr>
<td>30</td>
<td>-</td>
<td>Growth hormone, glucose</td>
</tr>
<tr>
<td>60</td>
<td>-</td>
<td>Growth hormone, glucose</td>
</tr>
<tr>
<td>90</td>
<td>-</td>
<td>Growth hormone, glucose</td>
</tr>
<tr>
<td>120</td>
<td>-</td>
<td>Growth hormone, glucose</td>
</tr>
<tr>
<td>180</td>
<td>-</td>
<td>Growth hormone, glucose</td>
</tr>
</tbody>
</table>

**Samples**

- **Growth Hormone**: 1 mL clotted blood (white top)
- **Glucose**: 0.5 mL venous blood in a fluoride oxalate tube (yellow top)

**Interpretation**

- Normal subjects will exhibit suppression of GH to <0.7 µg/L during the test.
- High basal levels which fail to suppress, sometimes with a paradoxical rise in GH levels is characteristic of GH hypersecretion.
- A paradoxical rise in GH may occur during the OGTT during normal adolescence.
- GH may fail to suppress due to chronic renal failure, liver failure, active hepatitis, anorexia nervosa, malnutrition, hyperthyroidism, diabetes and adolescence.
- Basal IGF-1 and IGFBP3 levels may be a useful adjunct. Patients with untreated acromegaly consistently have significantly raised random serum IGF-1 and IGFBP-3 levels, showing no overlap with normal individuals.

**References**

IGF-1 Generation Test

**CWS Test Name:** None – Please request tests separately

**Principle**  
Growth hormone is administered to the patient where there is strong suspicion of growth hormone insensitivity. This is generally indicated by short stature with low IGF-1 levels and a normal or high response to GH provocation tests. Growth hormone should stimulate the generation of IGF-1 which is measured in basal and stimulated blood samples. Failure of IGF-1 generation is suggestive of growth hormone insensitivity. With a sensitivity of 77 – 91% and a specificity <97% this test is generally useful only in detecting more severe cases of growth hormone insensitivity.

**Indication**  
- Diagnosis of growth hormone insensitivity

**Precautions**  
- None reported

**Side Effects**  
- No significant effect of short term Growth hormone use

**Preparation**  
- None required

**Protocol**  
1. **Day 1** – take blood sample for IGF-1 estimation  
2. **Administer growth hormone sub-cutaneously to patient at a dose of 0.1 U/kg body weight/day (i.e. 33 mcg/kg body weight/day)** for 4 days (days 1, 2, 3, 4)  
3. **Day 5** – take blood sample for IGF-1 estimation

**Time Points:**

<table>
<thead>
<tr>
<th>Day of test</th>
<th>Procedure</th>
<th>Blood Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Administer Growth Hormone</td>
<td>IGF-1</td>
</tr>
<tr>
<td>2</td>
<td>Administer Growth Hormone</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Administer Growth Hormone</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Administer Growth Hormone</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>IGF-1</td>
</tr>
</tbody>
</table>

**Samples**  
*IGF-1*  
1 mL clotted blood (white top)

**Interpretation**  
- An incremental increase in IGF-1 of >15 mcg/L above the baseline level excludes severe GH insensitivity

**References**  
**Water Deprivation Test**

**CWS Test Name:** None – Please request tests separately

*This test is potentially dangerous and must be undertaken with great care. Patients unable to conserve water may rapidly become severely hypertonic during this test.*

**Arrangements for carrying out a Water deprivation Test:**

When a decision is taken, either in clinic or on the ward, to perform a water deprivation test, to arrange for this test, please action as follows:

1. Inform Paediatric Endocrine Secretary
   - Drs Padidela / Skae x11628 Joanne Davis
   - Drs Ehtisham / Mughal x11678 Janet Hughes
   - Drs Banerjee / Clayton / Patel x11632 Sue Wilkinson

2. Secretary to contact Anne Shenton on x12233, Paediatric Lead in Biochemistry, with information regarding time line for performing these tests and underlying diagnosis. (Contact the paediatric Duty Biochemist on x12255 if difficulty in getting through to Anne Shenton)
   - State if urgent or routine

3. Biochemistry provides Endocrine secretary with feasible dates

4. Secretary to discuss with ETC for booking admission on one of the days feasible for biochemistry
   - Admission will be on Short Stay Ward from approx 4.00 pm for overnight stay for bloods/osmolality etc. as per protocol, followed by early morning admission on MIU early the following morning for Water Deprivation Test

5. Secretary informs endocrine doctors and biochemistry about the date agreed with the ETC and the family.
Endocrine Dynamic Function Test Protocols for use in Neonates and Children

**Principle**
Water restriction in normal individuals results in the secretion of AVP from the posterior pituitary in order to reabsorb water from the distal renal tubules and concentrate urine. Failure of this mechanism occurs in diabetes insipidus (DI), resulting in a rise in plasma osmolality, due to water loss, and a dilute urine of low osmolality. The concentrating mechanism for urine is maintained in compulsive water drinking (CWD). Cranial DI is caused by a failure of AVP secretion whilst nephrogenic DI is caused by insensitivity of the renal tubules to AVP. The two forms of DI can be distinguished by the administration of Desamino-D-AVP (DDAVP; synthetic AVP).

**Indication**
- This test is used to distinguish DI from primary polydipsia and to investigate suspected cranial or nephrogenic DI.
- A subjective thirst score may be performed at the same time and requires copies of the unit-less 100 mm linear visual analogue scale.

**Precautions**
- This test should not be performed if there is evidence of the kidney’s ability to concentrate urine e.g. spot urine osmolality >750 mmol/kg.
- Other causes of polyuria and polydipsia **MUST** be excluded before proceeding with the test. These include:
  - Diabetes mellitus
  - Hypoadrenalism
  - Hypercalcaemia
  - Hypokalaemia
  - Hypothyroidism
  - Urinary infections
  - Chronic kidney disease
  - Therapy with carbamazepine, chlorpropamide or lithium

Cortisol insufficiency must be treated prior to doing a water deprivation test as it interferes with the ability to excrete water and can mask DI.

**Side Effects**
- Patients with true DI may become severely water depleted during this test and **MUST** be carefully monitored (by weighing the patient and quantifying urine output regularly) throughout the test.

**Preparation**
*The laboratory **MUST** be notified AT LEAST 24 hrs before the test, ideally with more notice. Please see instructions on previous page. Osmolality results are required as soon as possible after the specimens have been collected.*

- Before considering the test, polyuria must be established with an accurate 24 hr urine output measurement. Urine output >4 mL/kg/hr in infants and children is suggestive of polyuria.
- The overnight test is reserved for situations where the diagnosis cannot be easily made by stopping oral fluid intake for a few hours and obtaining sodium and osmolality measurements.
- Children with massive polyuria (>4L/24 hr) should start the test in the morning when medical staff are present as the test will usually last 2 – 4 hrs.
- Thyroid and adrenal function must be normal or adequately replaced.
- The patient must be kept under close surveillance throughout the test to avoid surreptitious water drinking and in order to be monitored for any signs of dehydration.
Protocol

1. The night before the test (at 2200h), take blood for plasma osmolality, urea and electrolytes and glucose.
   - The test can only be carried out if the plasma osmolality is <295 mmol/kg.
   - Plasma osmolality can be calculated from the urea, electrolyte and glucose results using the formula:
     \[2 \times \text{Na} + \text{K} + \text{Glucose} + \text{Urea}\]
   - The osmolality sample will be analysed by the lab first thing in the morning before the test commences.

2. If the test is to proceed, weigh the patient undressed, record the weight and insert a reliable i.v. cannula.

3. Assess the patient:
   - If there is a low level of suspicion of DI and the patient is >2 years of age, stop all fluid intake at midnight.
   - If there is a high index of suspicion of DI (i.e. patients are polyuric or borderline hyperosmolar), or if the child is <2 years of age, fluid restriction should commence in the morning.

4. At 0900h weigh the patient undressed and record the weight. Calculate and record 5% of the weight. Collect blood and urine samples for osmolality, urea and electrolyte measurements. These should be sent immediately to the Biochemistry laboratory.
   - If the osmolality is >295 mmol/kg the water deprivation test must not be undertaken.

5. Continue to weigh the child hourly and simultaneously collect blood and urine samples for osmolality measurements. Ensure that the child is undressed on each occasion. The weight should be recorded and the test terminated, with DDAVP given as in step 9, if 5% of the initial body weight is lost.

6. The test is normally continued until 3 consecutive urines have shown a total rise in urine osmolality of <30 mmol/kg (normally about 12 midday) or until either:
   - The urine osmolality exceeds 750 mmol/kg (or 500 mmol/kg in infants)
   - 5% of initial weight is lost or thirst is unbearable
   - Plasma osmolality exceeds 300 mmol/kg

   N.B. It may be necessary to prolong the test in compulsive water drinking, especially if the child has been drinking excessively immediately prior to the start.

7. At 12 midday, or when the test is terminated, take blood samples for urea, electrolytes and osmolality along with a urine sample for osmolality. This urine sample can also be stored and used to measure AVP if required.
   - N.B. If 5% weight loss or extreme distress occurs give DDAVP (5 mcg intra-nasally or 0.3 microgram i.m.) and free fluids immediately after test is terminated.

8. If the child shows no evidence of urinary concentration, proceed with the DDAVP test to allow differentiation between central and nephrogenic DI.

DDAVP Test

1. Allow the patient to drink but not excessively or a dilutional hyponatraemia may occur.
   - N.B. Fluid intake should be no more than twice the volume of urine passed during fluid restriction. Fluid intake should be monitored closely.

2. Give DDAVP as follows:
   - Children aged 12 – 18 years should receive 2 mcg i.m. or 20 mcg intra-nasally
   - Children aged 2 to 12 years 0.5 – 1 mcg i.m. or 10 – 20 mcg intra-nasally

3. Collect blood and urine samples for osmolality hourly (if possible) for the next 4 hours. Stop if the urine osmolality reaches >750 mmol/kg.
### Samples

**Na, K, Urea & Plasma Osmolality**  
1 mL lithium heparin blood (orange top)

**Glucose**  
1 mL venous blood in a fluoride oxalate tube (yellow top)

**Urine osmolality**  
1-2 mL urine in a plain bottle

**AVP**  
20 mL urine in plain bottle. **Send to Biochemistry laboratory immediately for freezing.** This sample will only be sent for analysis if the urine and plasma osmolality results are equivocal.

### Interpretation

**Normal and CWD:**  
Plasma osmolality does not exceed 295 mmol/kg and the urine osmolality rises three-fold to >750 mmol/kg.

**Central DI:**  
Plasma osmolality >295 mmol/kg with inappropriately dilute urine (<300 mmol/kg). DDAVP produces normally concentrated urine.

**Nephrogenic DI:**  
As for Central DI, but DDAVP produces no response.

**Partial DI:**  
Patients have moderate elevation of plasma osmolality and urine osmolality typically between 300-750 mmol/kg.
22:00 Take blood for U&E and glucose
Calculate plasma osmolality

*If Plasma Osmolality >295 mmol/kg DO NOT proceed with test*

Stop fluid intake in patients > 2 yrs with low level of suspicion of DI

09:00 Take blood for U&E and plasma osmolality
Collect urine for osmolality.
Weigh child undressed. Record 5% of body weight

*If Plasma Osmolality >295 mmol/kg DO NOT proceed with test*

Stop fluid intake in patients < 2 yrs and those with high level of suspicion of DI

Hourly: Take blood for U&E and plasma osmolality
Collect urine for osmolality
Weigh child undressed and record weight

If urine osmo > 750 mmol/kg

**Terminate the test**
Take blood for U&E & plasma osm
Collect urine for osm

No need for DDAVP

If weight loss 5% OR extreme distress OR plasma osm > 300 mmol/kg

**Terminate the test**
Take blood for U&E & plasma osm
Collect urine for osm & AVP

Give DDAVP

3 consecutive urines show a total rise in osm of <30 mmol/kg

OK for patient to drink water

**Hourly**: Take blood for plasma osmolality
Collect urine for osmolality

**Terminate test after 4 hours, or if urine osm reaches >750 mmol/kg**

**References**

Hypertonic Saline Infusion Test

CWS Test Name: None – Please request tests separately

This test is potentially dangerous and must be undertaken with great care. Patients unable to conserve water may rapidly become severely hypertonic during this test. This test requires a doctor to be present throughout.

Principle
This test is designed to stress the integrity of the renal-AVP axis, in order to assess posterior pituitary function, providing reliable information regarding the relation between plasma osmolality and AVP. The infusion of hypertonic saline raises plasma osmolality and ensures maximal stimulation of AVP secretion. The failure of maximal renal concentration of urine does not help differentiate which organ is performing sub-optimally. The diagnosis can be seen by comparing the response of plasma AVP to plasma osmolality using the Newcastle chart (Prof P.H. Baylis).

Indication
• This test is performed if the results of the water deprivation test are equivocal: the test can be useful in differentiating partial forms of diabetes insipidus and to demonstrate normal osmoregulation in patients with primary polydipsia. This test is also indicated when investigating patients with adipsic or hypodipsic hypernatraemia. A subjective thirst score maybe performed at the same time and requires copies of the unit-less 100 mm linear visual analogue scale.

Precautions
• Contraindicated in patients with epilepsy, cerebral or cardiovascular disease.

Side Effects
• There is a serious risk of dehydration in patients with DI
• The hypertonic saline may induce thrombophlebitis at the site of infusion.

Preparation
The laboratory MUST be notified AT LEAST 24 hrs before the test, ideally with more notice. Osmolality results are required as soon as possible after the specimens have been collected.

• Overnight food fast from midnight the day before the test
• Only water maybe drunk until the time of the test; other drinks are not permitted after midnight.
• No smoking during period of food fast
• Absolute food/fluid fast during the infusion period
• Assess to exclude the presence of any confounding factor e.g. hypercalcaemia, hypokalaemia, glycosuria or any other cause of a dilute solute diuresis, prior to commencing the test.
• Cortisol insufficiency must be treated prior to doing a water deprivation test as it interferes with the ability to excrete water and can mask DI.

Protocol
1. Patient instructed to empty bladder. Measure urine volume and osmolality
2. Weigh patient
3. Patient to lie supine where they will remain for the remainder of the test.
4. Insert cannula into antecubital veins of both arms. Allow patient to rest for 30 min.
5. Blood pressure monitored every 5 min during the 30 min preceding the test and throughout the infusion period.
6. Take blood into chilled Li Heparin tube.
7. Repeat blood sample after 15 min
8. Begin infusion of 5% (0.85 mol/L) saline at 0.05 mL/kg/min for 2 hours into non-blood sampling arm via an indwelling cannula for a max of 3 hrs or until a plasma osmolality of 300 mmol/kg is achieved.
9. Take blood samples at 30 min intervals for AVP and osmolality
10. Measure volume and osmolality on all urine passed.

**Note time at which thirst is noted - if patient very thirsty during test, give ice chips**

11. Take final blood sample 15 min after completion of infusion.
12. Record blood pressure, urine volume, blood sampling, patients comments
13. Allow patient to drink after test. Avoid ingestion of large fluid volumes.

**Samples**

<table>
<thead>
<tr>
<th>Plasma osmolality</th>
<th>1 mL lithium heparin blood (orange top)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVP</td>
<td>4 mL blood in a lithium heparin tube (orange top). <strong>Send on ice to Biochemistry laboratory immediately for centrifugation and freezing.</strong></td>
</tr>
</tbody>
</table>

**Interpretation**

Patients with primary polydipsia or nephrogenic diabetes insipidus have normal AVP release in response to the hyperosmolar state induced by this procedure. Patients with cranial diabetes insipidus have little or no rise in AVP.

**Newcastle Chart: Relation between plasma arginine vasopressin (AVP) and plasma osmolality following hypertonic 5% saline infusion**

The shaded area shows the response of a normal individual. The hatched area is those individuals with cranial DI.

**References**

**TRH Test**

**CWS Test Name:** TRH

**Principle**
TRH is used to stimulate the pituitary gland in order to assess the hypothalamic-pituitary-thyroid axis.

**Indication**
- The TRH test is used in the investigation of secondary hypothyroidism and allows for differential diagnosis of pituitary and hypothalamic causes of TSH deficiency.

**Precautions**
- Patients should be off thyroxine for 3 weeks prior to test, so it is rarely used in children on thyroxine.

**Side Effects**
- There are a number of reports in the literature of apoplexy post TRH in patients with pituitary adenoma. This is very rare, but patients should be counselled to contact the endocrine team if headaches or illness occur post test.
- The test may cause mild flushing, nausea, headaches, abdominal and chest discomfort and a desire to micturate. Symptoms are usually seen at the time of injection.

**Preparation**
- Patient does not need to be fasted (unless combined with a test of GH secretion).
- Asthmatic patients should be carefully monitored throughout the test.
- As TRH may cause patients a desire to micturate, older children should be asked to empty their bladder before the test commences.
- Order the TRH (protirelin) from pharmacy at least 24 hours in advance.
- This test can be done in conjunction with other pituitary function testing. See **Combined test of anterior pituitary function**

**Protocol**
1. Insert an indwelling cannula and take baseline bloods for TSH and free T4 (t = 0).
2. **Inject TRH slowly i.v. over 2 minutes. Use a dose of 5-7 mcg/kg body weight to a maximum of 200 mcg.** This should be completed whilst the patient is supine as side effects are most likely to occur during this period of time.
3. Take further blood samples for TSH and fT4 20 and 60 min following the administration of TRH.

**Time Points:**

<table>
<thead>
<tr>
<th>Time</th>
<th>Procedure</th>
<th>Blood Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Administer TRH i.v.</td>
<td>TSH, fT4</td>
</tr>
<tr>
<td>20</td>
<td>-</td>
<td>TSH</td>
</tr>
<tr>
<td>60</td>
<td>-</td>
<td>TSH</td>
</tr>
</tbody>
</table>

**Samples**
- **TSH and fT4**
  - 2 mL clotted blood (white top)
Interpretation
- A normal response is a TSH peak of 10 – 30 mU/L at 20 min, which will decrease by 60 min.
- An exaggerated response is often seen if basal TSH is elevated (BUT the test should only be used to investigate secondary hypothyroidism).
- In pituitary disease, TSH response is poor.
- A hypothalamic response is indicated by a peak at 20 min which remains elevated at 60 min.
- In both pituitary and hypothalamic types of TRH response, a low fT4 value may indicate need for replacement.

References
**Pentagastrin Stimulation Test**

**CWS Test Name:** None – Please request tests separately

**Principle**
Calcitonin may be secreted by the C-cells of the thyroid gland. High levels may suggest C cell hyperplasia or Medullary Thyroid Carcinoma (MTC). In very early disease (or screening for familial syndromes) levels may not be raised, but may be stimulated by pentagastrin. It is suggested that borderline baseline levels of Calcitonin are further investigated by stimulation.

**Indication**
- Screening for MTC in MEN2 patients or their relatives

**Precautions**
- Hypocalcaemia
- Hypertension
- Asthma

**Side Effects**
- Transient flushing
- Nausea
- Abdominal cramps
- Dizziness
- Bradycardia
- ‘Panic Attack’ like symptoms, shortness of breath

**Preparation**
- Only perform this test under medical supervision
- Fast patient for 12 hrs pre-test with only water to drink.
- Pentagastrin needs dilution before the test. An ampoule contains 250 mcg/mL. Add 1 mL pentagastrin to 9 mL of 0.9% saline to give a concentration of 25 mcg/mL. This equates to a dose of 0.02 mL/kg.

**Protocol**
*All blood samples for Calcitonin MUST be taken in chilled tubes on an iced slurry. Specimens MUST be sent to the lab immediately as Calcitonin is very unstable ex-vivo.*

1. Weigh patient and insert a reliable cannula
2. Take a basal sample (t = 0) for calcitonin
3. **Inject pentagastrin i.v. over a 15 second period using a dose of 0.5 mcg/kg body weight** (0.02 mL/kg of diluted pentagastrin prepared as above)
4. Take blood samples 2, 3, 5, and 10 min following pentagastrin administration. Use a timer as calcitonin peaks 2 – 3 min post injection.
5. Samples must be taken onto iced slurry and transferred immediately to the lab as calcitonin is very unstable ex-vivo

**Time Points:**

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Procedure</th>
<th>Blood Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>Calcitonin</td>
</tr>
<tr>
<td>0</td>
<td>Inject Pentagastrin over 15 sec</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>Calcitonin</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>Calcitonin</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>Calcitonin</td>
</tr>
<tr>
<td>10</td>
<td>-</td>
<td>Calcitonin</td>
</tr>
</tbody>
</table>
**Samples**

*Calcitonin*  
2 mL clotted blood (white top)

*Specimens MUST be sent to the lab immediately as Calcitonin is very unstable ex-vivo.*

**Interpretation**

- A rise of <10 ng/L is seen in healthy patients.

- A rise of plasma calcitonin to >100 ng/L is suggestive of C-cell hyperplasia and should be investigated further for MTC.

- A rise of between 10 and 100 ng/L is equivocal and may require further investigation depending upon the clinical picture.

**References**

**Gonadotrophin-releasing hormone (GnRH) test**

**CWS test name:** GnRH STM TEST or LHRH

**Principle**
Gonadotrophin-releasing hormone (GnRH), secreted by the hypothalamus, stimulates the release of luteinising hormone (LH) and follicle-stimulating hormone (FSH) from the anterior pituitary gland.

**Indication**
- Investigation of pubertal disorders: precocious puberty and delayed puberty.
- Investigation of hypogonadotrophic hypogonadism suspected pre-pubertally.

**Precautions**
- Avoid HCG injections prior to the test and do not perform following priming for an arginine test.

**Side Effects**
- GnRH may rarely cause nausea, headache and abdominal pain.

**Preparation**
The patient need not be fasted (unless combined with a test of GH secretion).

**Protocol**
1. Insert a reliable cannula. Take blood for LH, FSH, testosterone or oestradiol (t = 0).
2. **Give a bolus dose of GnRH i.v.** 2.5 mcg/kg for children < 1 yr
   100 mcg for children > 1 yr
3. Take blood at + 30 min
   + 60 min
   after the GnRH bolus for LH & FSH only

**Samples**
- **LH & FSH** 1 mL lithium heparin (orange top)
- **Testosterone or Oestradiol** 2 mL clotted blood (white top)

**Interpretation**
The GnRH test should be interpreted in the clinical context (including pubertal staging, testicular volume/ovarian ultrasound) and along with other biochemical markers of puberty such as serum oestradiol or testosterone levels.

**Prepubertal**
Basal LH usually <1 IU/L. LH peak post-GnRH <5 IU/L. FSH peak greater than LH peak.

**Peripubertal**
Higher increments, especially if LH dominant, provide evidence of a pubertal pattern of gonadotrophin response. LH peak >5 IU/L, with LH peak greater than FSH peak.

See Table 1 on the following page for the reference ranges from Resende et al. 2007, for serum LH and FSH concentrations (AutoDELFIA assays) in normal subjects at different pubertal stages (n=316 for basal levels, n=106 for GnRH stimulated levels).

**Pubertal Delay and Pubertal failure**
In children with suspected hypogonadotrophic hypogonadism, a complete lack of response supports the diagnosis. A measurable but low response has limited predictive value (may also occur in constitutional delay of puberty). In primary gonadal failure, the basal LH and FSH are elevated and the response to GnRH is exaggerated. High basal FSH levels in the presence of low oestradiol levels may suggest ovarian failure.
**Premature thelarche and thelarche variant**
There may be a FSH predominant response, with LH usually in the pre-pubertal range.

**Precocious puberty**
In gonadotrophin-independent precocious puberty, spontaneous gonadotrophin secretion is suppressed by the autonomous sex steroid secretion: basal LH and FSH are low and the response to GnRH is flat.

In gonadotrophin-dependent precocious puberty basal LH and FSH levels are usually elevated and the response to GnRH is exaggerated. A LH dominant rise is usually observed, with LH levels usually >7 IU/L and more commonly >10 IU/L in established puberty.

**Precocious puberty (treated)**
Suppressed basal LH and FSH and flat response to GnRH indicate adequate treatment with GnRH analogues.

**Table 1** - Concentration of serum LH and FSH (AutoDELFIA assays), expressed as mean and 5th and 95th percentiles, in normal subjects at different pubertal stages (n=316 for basal levels, n=106 for GnRH stimulated levels)

<table>
<thead>
<tr>
<th>Pubertal Stage</th>
<th>Males</th>
<th></th>
<th></th>
<th>Females</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basal</td>
<td>GnRH-stimulated peak</td>
<td>Basal</td>
<td>GnRH-stimulated peak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LH (IU/L)</td>
<td>FSH (IU/L)</td>
<td>LH (IU/L)</td>
<td>FSH (IU/L)</td>
<td>LH (IU/L)</td>
<td>FSH (IU/L)</td>
<td></td>
</tr>
<tr>
<td>T1 (2.6 yr)</td>
<td>&lt;0.6</td>
<td>1.0 (1.0-1.4)</td>
<td>N/A</td>
<td>N/A</td>
<td>&lt;0.6</td>
<td>3.7 (1.0-8.3)</td>
</tr>
<tr>
<td>T1&lt;sub&gt;2&lt;/sub&gt;</td>
<td>&lt;0.6</td>
<td>1.1 (1.1-1.6)</td>
<td>2.2 (1.1-3.3)</td>
<td>5.7 (2.4-10.6)</td>
<td>&lt;0.6</td>
<td>1.6 (1.0-3.4)</td>
</tr>
<tr>
<td>TII</td>
<td>1.3 (0.6-2.7)</td>
<td>1.8 (1.0-4.3)</td>
<td>15.6 (1.9-31.0)</td>
<td>3.6 (1.4-10.2)</td>
<td>1.0 (0.6-N/A)</td>
<td>2.3 (1.0-4.8)</td>
</tr>
<tr>
<td>TIII</td>
<td>1.4 (0.6-2.5)</td>
<td>2.1 (1.0-5.5)</td>
<td>16.1 (7.3-32.0)</td>
<td>4.2 (1.1-13.0)</td>
<td>2.9 (0.6-5.0)</td>
<td>3.9 (2.6-5.1)</td>
</tr>
<tr>
<td>TV</td>
<td>1.6 (0.7-2.5)</td>
<td>2.1 (1.0-5.2)</td>
<td>17.3 (12.0-28.0)</td>
<td>4.8 (1.7-12.0)</td>
<td>3.1 (1.0-6.0)</td>
<td>4.0 (1.5-7.2)</td>
</tr>
<tr>
<td>LH (IU/L)</td>
<td>4.7 (2.4-8.2)</td>
<td>3.2 (1.2-5.7)</td>
<td>28.9 (9.5-56.3)</td>
<td>5.3 (1.8-12.0)</td>
<td>5.7 (0.6-15.4)</td>
<td>4.1 (1.0-7.3)</td>
</tr>
</tbody>
</table>

**References**

Royal Manchester Children's Hospital
3 day HCG Stimulation Test

CWS Test Name: None – Please request tests separately

**Principle**

hCG is a polypeptide hormone and shares a common subunit with LH. It stimulates testicular Leydig cells to secrete androgens via the LH receptors. Children aged 6 months to 8 years frequently have undetectable basal gonadal steroids in plasma and gonadal function can only be assessed by Leydig cell stimulation using hCG.

**Indication**

- To detect functioning testicular tissue in the investigation of male hypogonadism, ambiguous genitalia, micropenis, delayed puberty and/or undescended testes. The test should be performed even if the gonads are impalpable (and the karyotype is XY or XY mosaic).
- To define enzyme blocks in testosterone biosynthesis.

**Precautions**

- In boys with normal testes there may be some virilisation (increase in testicular size, erections).
- The test should not be performed before 2 weeks of age.
- If a GnRH test is planned, this should be carried out before the HCG test (or > 6 weeks after) as HCG has a long half-life.

**Side Effects**

- Headaches and/or tiredness are reported side effects

**Preparation**

- None required

**Protocol**

3 Day Protocol:

1. **Day 1** - Between 8.00 a.m. and 9.00 a.m. collect baseline blood samples for testosterone (also androstenedione and dihydrotestosterone if a steroid biosynthetic defect is suspected).

2. Immediately following collection of baseline blood samples, give hCG i.m. as follows:
   - 500 IU if weight < 5kg
   - 1000 IU if weight 5 - 10kg
   - 1500 IU if weight 10 - 15kg
   - 3000 IU if weight above 15kg

3. **Day 4** - Repeat blood sample 72 hours after hCG injection for testosterone, dihydrotestosterone and androstenedione.

If the results of the 3 day test are equivocal then consider performing the 3 week hCG stimulation test.

**Samples**

- **Testosterone, DHT & Androstenedione**
  - 4 mL clotted blood (white top)

- **Urinary Steroid Profiling**
  - 24h urine in a plain bottle if indicated

**Interpretation**

The normal testosterone response depends on the age of the patient. In infancy, a normal testosterone increment after hCG may vary from 2-fold to 10- or even 20-fold. During childhood, the increment is between 5- and 10-fold. During puberty, as the basal concentration is higher, the increment is less, i.e. 2- to 3-fold. In the absence of testes, no response to testosterone occurs.

An absent response with an exaggerated LH/FSH response to LHRH stimulation indicates primary gonadal failure or anorchia. If there is a defect in testosterone biosynthesis, there will be an increase in precursor steroid secretion following HCG stimulation.
In normal male children (6 months – puberty) the T/DHT ratio is <20 before HCG stimulation and <27 after HCG stimulation. In 5α-reductase deficiency the T/DHT ratio is <20 before HCG stimulation but >27 after stimulation. There are reported errors in the interpretation of the hCG stimulation test in boys ~8yrs of age with increased Testosterone:DHT in the 5α-reductase range.

In 17β-hydroxysteroid dehydrogenase deficiency the androstenedione:testosterone ratio is >20 post hCG.

Samples are sent to Leeds General Infirmary for analysis. Leeds have recently changed their interpretation cut offs following a change to LCMSMS measurement rather than previously validated RIA results as follows:

<table>
<thead>
<tr>
<th>Testosterone (nmol/L)</th>
<th>DHT (nmol/L)</th>
<th>T/DHT ratio after hCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal male adults</td>
<td>8 - 27</td>
<td>&lt; 2.9</td>
</tr>
<tr>
<td>Normal children (6 months – puberty)</td>
<td>&lt; 0.9</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>5α-reductase deficiency (6 months – puberty)</td>
<td></td>
<td>&gt; 12</td>
</tr>
</tbody>
</table>

References


3 week HCG Stimulation Test

CWS Test Name: None – Please request tests separately

Principle
hCG is a polypeptide hormone and shares a common subunit with LH. It stimulates testicular Leydig cells to secrete androgens via the LH receptors. Children aged 6 months to 8 years frequently have undetectable basal gonadal steroids in plasma and gonadal function can only be assessed by Leydig cell stimulation using hCG.

Indication
- In the event of an equivocal result from the 3 day HCG stimulation test, the 3 week HCG stimulation test should be used.

Precautions
- In boys with normal testes there may be some virilisation (increase in testicular size, erections).
- The test should not be performed before 2 weeks of age
- If a GnRH test is planned, this should be carried out before the HCG test (or > 6 weeks after) if as hCG has a long half-life.

Side Effects
- Headaches and/or tiredness are reported side effects

Preparation
- None required

Protocol
3 Week Protocol:
*Described in table on following page*

1. Day 1 - Between 8.00a.m and 9.00a.m collect baseline blood samples for testosterone (also androstenedione and dihydrotestosterone if a steroid biosynthetic defect is suspected).

2. Immediately following collection of baseline blood samples, give hCG i.m. as follows:
   - 500 IU if weight < 5kg
   - 1000 IU if weight 5 - 10kg
   - 1500 IU if weight 10 - 15kg
   - 3000 IU if weight above 15kg

3. Day 4 - Repeat blood sample 72 hours after HCG injection for testosterone, dihydrotestosterone and androstenedione.

4. Continue to administer hCG twice weekly for the next 2 weeks.

5. Collect the final blood sample for testosterone, DHT and androstenedione 4 days after the last injection of hCG.

Collection of 24h urine samples before and 20 days after the first hCG stimulation (i.e. with last set of blood samples) for measurement of steroid metabolites may be useful in investigation of defects in testosterone biosynthesis.

Also document the clinical response in terms of testicular descent and change in phallic size.
Endocrine Dynamic Function Test Protocols for use in Neonates and Children

Time Points:

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>Mon</td>
<td>Thurs</td>
<td>Mon</td>
<td>Thurs</td>
</tr>
<tr>
<td>hCG administration</td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Blood Sample for testosterone, DHT, A-dione</td>
<td></td>
<td>√</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Urine Steroid profile</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
</tr>
</tbody>
</table>

Samples

**Testosterone, DHT & Androstenedione** 4 mL clotted blood (white top)

**Urinary Steroid Profiling** 24h urine in a plain bottle if indicated

Interpretation

The normal testosterone response depends on the age of the patient. In infancy, a normal testosterone increment after hCG may vary from 2-fold to 10- or even 20-fold. During childhood, the increment is between 5- and 10-fold. During puberty, as the basal concentration is higher, the increment is less, i.e. 2- to 3-fold.

An absent response with an exaggerated LH/FSH response to LHRH stimulation indicates primary gonadal failure or anorchia. If there is a defect in testosterone biosynthesis, there will be an increase in precursor steroid secretion following HCG stimulation.

In normal male children (6 months – puberty) the T/DHT ratio is <20 before HCG stimulation and <27 after HCG stimulation. In 5α-reductase deficiency the T/DHT ratio is <20 before HCG stimulation but >27 after stimulation. There are reported errors in the interpretation of the hCG stimulation test in boys ~8yrs of age with increased Testosterone:DHT in the 5α-reductase range.

In 17β-hydroxyoosteroid dehydrogenase deficiency the androstenedione:testosterone ratio is >20 post hCG.

A 5- to 10-fold increment from the basal testosterone constitutes a normal response in the prolonged test.

Samples are sent to Leeds General Infirmary for analysis. Leeds have recently changed their interpretation cut offs following a change to LCMSMS measurement rather than previously validated RIA results as follows:

<table>
<thead>
<tr>
<th>Testosterone (nmol/L)</th>
<th>DHT (nmol/L)</th>
<th>T/DHT ratio after hCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal male adults</td>
<td>8 - 27</td>
<td>&lt; 2.9</td>
</tr>
<tr>
<td>Normal children (6 months – puberty)</td>
<td>&lt; 0.9</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>5α-reductase deficiency (6 months – puberty)</td>
<td>&lt; 0.5</td>
<td></td>
</tr>
</tbody>
</table>

References

**Oral Glucose Tolerance Test**

**CWS Test Name:** GLU.TOL.TEST

**Principle**

In normal individuals pancreatic insulin secretion maintains blood glucose within a tight concentration range following an oral glucose load. Failure of insulin secretion, or resistance to insulin action, will result in an elevation in blood glucose. The Glucose Tolerance Test is usually used to exclude/confirm a diagnosis of Glucose intolerance or Type 2 Diabetes Mellitus. The test is unnecessary if a child has characteristic symptoms of diabetes (e.g. weight loss, thirst, polyuria) and either a random venous plasma laboratory glucose concentration of ≥ 11.1 mmol/L, or a fasting concentration of ≥ 7.0 mmol/L.

**Indication**

- The oral glucose tolerance test is used to clarify borderline elevation in fasting plasma glucose. The OGTT is not indicated when a patient has an unequivocally elevated fasting or random plasma glucose. An OGTT only needs to be performed in a child with an equivocal result for the diagnosis of diabetes.

**Precautions**

- This test is only necessary if fasting glucose measurements are equivocal i.e. 5.6 - <7.0 mmol/L.
- This test should not be performed in patients who fulfil the criteria for diabetes mellitus: Two diagnostic glucose results on separate occasions (either fasting plasma glucose ≥ 7.0 mmol/L or random plasma glucose of ≥ 11.1 mmol/L), or one diagnostic glucose result and clinical symptoms of diabetes e.g. polydipsia, polyuria, ketonuria and rapid weight loss.
- Do not perform glucose tolerance tests on patients with uncontrolled thyroid dysfunction or patients who are under physical stress e.g. post surgery, trauma or infection or extreme psychological stress as these may give misleading results due to altered insulin sensitivity in these circumstances.
- This test should also not be performed on patients with hypokalaemic periodic paralysis.

**Side Effects**

Some patients feel nauseated and may have vasovagal symptoms during this test.

**Preparation**

- Before subjecting a patient to an OGTT ensure that there has been an appropriate diagnostic work-up (see WHO guidelines).
- Ensure that the child has had an adequate diet (minimum of 150 g/day of carbohydrate) for at least 5 days before the test.
- Fast the patient overnight (4 hours for infants) but avoid more prolonged fasting. Drinks of water (no sweet drinks) are allowed during this period.
- Physical exercise is not allowed in morning prior to and/or during the test
- Test should be performed in the morning

**Protocol**

1. Ensure the patient's fasting blood glucose concentration, checked with a capillary blood sample obtained by finger prick testing with a glucometer, is ≤7 mmol/L before proceeding with the test. If the result is higher, take a venous blood sample and send it to the lab to confirm the glucometer result.

2. Prepare the glucose load using ONE of the following:
   - **POLYCAL® (Nutricia Clinical) liquid** (contains 0.66g anhydrous glucose per mL; 1.51 mL = 1g anhydrous glucose): Dose of POLYCAL must be adjusted for the weight at a dose of 2.64 mL POLYCAL/kg body weight (maximum dose 113 mL POLYCAL, equivalent to a 75g glucose load).
     OR
   - **Anhydrous glucose**: Dose 1.75 g/kg body weight (maximum dose 75g diluted in 200 mL water).
     OR
   - **Lucozade Energy Original**: Lucozade can be used but great care must be taken to ensure it is the correct formulation (should be 70 kcal/100 mL). Dose: 9.57 mL/kg body weight (maximum dose 410 mL).
N.B. Lucozade is not an advised glucose challenge as the sodium in the drink may influence the rate of glucose uptake by the Na/glucose co-transporters.

3. Take a basal sample for glucose (t = 0). Write “t = 0” on the tube of blood.

4. The child should drink the glucose load over a period of no more than 5 min. Note the time the glucose load is given on the request form.

5. Take a further blood sample 2hrs / 120 min after finishing the glucose drink. Record the time 2 hrs post glucose load on the request form. Write “t=120” on the tube of blood.

**Samples**

**Glucose**

1 mL venous blood in a fluoride oxalate tube (yellow top)

If it is impossible to collect a venous sample, then 0.5 mL (minimum) capillary blood in a fluoride tube may be substituted. Please indicate clearly on the request form if this is the case. Samples taken at 0 and 120 min must always be the same type.

**Interpretation**

The flow chart on the following page indicates the diagnostic criteria for Diabetes mellitus.

Venous plasma:
- A fasting glucose level of >7 mmol/L or a level of >11.1 mmol/L 120 min post-glucose load confirms a diagnosis of diabetes mellitus.
- Levels between 7.8 – 11.0 mmol/L 120 min post glucose load indicate impaired glucose tolerance
- Values for diagnosing diabetes using different sample types are indicated in the table below:

<table>
<thead>
<tr>
<th>Glucose Concentration (mmol/L)</th>
<th>Glucose Concentration (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole blood</td>
</tr>
<tr>
<td></td>
<td>Venous</td>
</tr>
<tr>
<td><strong>Diabetes Mellitus</strong></td>
<td></td>
</tr>
<tr>
<td>Fasting</td>
<td>≥6.1</td>
</tr>
<tr>
<td>120 min post-glucose</td>
<td>≥10.0</td>
</tr>
<tr>
<td><strong>Impaired glucose tolerance</strong></td>
<td></td>
</tr>
<tr>
<td>120 min post-glucose</td>
<td>≥6.7 and &lt;10.0</td>
</tr>
<tr>
<td><strong>Impaired fasting glycaemia</strong></td>
<td></td>
</tr>
<tr>
<td>Fasting</td>
<td>≥5.6 and &lt;6.1</td>
</tr>
</tbody>
</table>

References
1. East Kent Hospitals University NHS Foundation Trust Clinical Biochemistry: OGTT – Protocol for paediatrics
Oral Glucose Tolerance Test with insulin

CWS Test Name: GLU.TOL.TEST

Principle
The increasing prevalence of obese children has also resulted in an increased number of children at risk of developing insulin resistance, which can lead to hyperinsulinaemia and eventually type 2 diabetes mellitus. In contrast to the diagnostic assessment of diabetes, the diagnosis of insulin resistance is less clear, depending on the given situation of an individual. There are no clear criteria to define insulin resistance in children at present.

Indication
- Obese patients with clinical signs of insulin resistance (acanthosis nigricans) and/or a family history of diabetes.

Precautions
- This test should not be performed in patients who fulfil the criteria for diabetes mellitus: Two diagnostic glucose results on separate occasions (either fasting plasma glucose $\geq 7.0$ mmol/L or random plasma glucose of $\geq 11.1$ mmol/L), or one diagnostic glucose result and clinical symptoms of diabetes e.g. polydipsia, polyuria, ketonuria and rapid weight loss.
- This test should not be performed on patients who are under physical stress e.g. post surgery, trauma or infection or extreme psychological stress as these may give misleading results.
- This test should not be performed on patients with hypokalaemic periodic paralysis.

Side Effects
Some patients feel nauseated and may have vasovagal symptoms during this test.

Preparation
- Before subjecting a patient to an OGTT ensure that there has been an appropriate diagnostic work-up (see WHO guidelines).
- OGTT must NOT be performed if the fasting capillary (finger prick) or venous blood glucose concentration is $> 7$ mmol/L or a random glucose $> 11$ mmol/L.
- Do not perform glucose tolerance tests on patients known to be suffering from an infection, patients with uncontrolled thyroid dysfunction, or patients recovering from severe stress (e.g. surgery) as these alter insulin sensitivity.
- Ensure that the child has had an adequate diet (minimum of 150 g/day of carbohydrate) for at least 5 days before the test.
- Fast the patient overnight (4 hours for infants) but avoid more prolonged fasting. Drinks of water (no sweet drinks) are allowed during this period.
- Physical exercise is not allowed in morning prior to and/or during the test.
- Test should be performed in the morning.

Protocol
1. Ensure the patient’s fasting blood glucose concentration, checked with a capillary blood sample obtained by finger prick testing with a glucometer, is $\leq 7$ mmol/L before proceeding with the test. If the result is higher, take a venous blood sample and send it to the lab to confirm the glucometer result.
2. Prepare the glucose load using ONE of the following:
   - POLYCAL® (Nutricia Clinical) liquid (contains 0.66g anhydrous glucose per mL; 1.51 mL $= 1$g anhydrous glucose): Dose of POLYCAL must be adjusted for the weight at a dose of 2.64 mL POLYCAL/kg body weight (maximum dose 113 mL POLYCAL, equivalent to a 75g glucose load).
     OR
   - Anhydrous glucose: Dose 1.75 g/kg body weight (maximum dose 75g diluted in 200 mL water).
     OR
   - Lucozade Energy Original: Lucozade can be used but great care must be taken to ensure it is the correct formulation (should be 70 kcal/100 mL). Dose: 9.57 mL/kg body weight (maximum dose 410 mL).
N.B. Lucozade is not an advised glucose challenge as the sodium in the drink may influence the rate of glucose uptake by the Na/glucose co-transporters.

3. Take a basal sample for glucose and insulin (t = 0). Write t = 0 on the tube of blood.

4. The child should drink the glucose load over a period of about 5 min. Note the time the glucose load is given on the request form.

5. Take further blood samples for glucose and insulin at 30 and 120 min after finishing the glucose drink. Record the time post glucose load on the request form and on the tube of blood.

### Time Points:

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Procedure</th>
<th>Blood Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Take blood then administer glucose load</td>
<td>Glucose, Insulin</td>
</tr>
<tr>
<td>120</td>
<td>-</td>
<td>Glucose, Insulin</td>
</tr>
</tbody>
</table>

### Samples

**Glucose** 1 mL venous blood in fluoride oxalate tube (yellow top)

**Insulin** 1 mL lithium heparin (orange top)

*Send IMMEDIATELY to laboratory on ice for centrifugation and freezing*

### Interpretation

The 2010 consensus statement recommends there is no clear cut-off to define insulin resistance in children and surrogate measures such as fasting insulin are not ideal.

The following cut-off values taken from SPEG² provide useful guidance:

- Fasting insulin is <10 mU/L in pre-pubertal children or children younger than 10 years or <20 mU/L in children post pubertal children.
- Peak insulin during the test is normally <100 mU/L.
- Fasting insulin of 20 - 50 mU/L or peak insulin of 100 - 300 mU/L is suggestive of mild to moderate insulin resistance.
- Fasting insulin of >50 mU/L or peak insulin of >300 mU/L is suggestive of severe insulin resistance.

### References


Endocrine Dynamic Function Test Protocols for use in Neonates and Children

Please discuss with Metabolic/Endocrine Team before carrying out this test. This fast is designed primarily for the use of the Metabolic and Endocrine teams at RMCH. All patients, prior to any fasting studies, should have been assessed and fat oxidation disorders, such as MCAD deficiency, excluded by appropriate investigations.

Management of hypoglycaemia
If at any time during the fast the child becomes hypoglycaemic with bedside finger prick glucometer reading < 2.6 mmol/L (but remember blood glucose [BG] levels are inaccurate at low levels) or if symptomatic, do the following without delay:

- take blood samples as listed as for the end of the fast (12 hours) and
- stop the fast immediately after the blood has been taken.
  - If symptomatic, give glucose (3 mL/kg of i.v. 10% Dextrose) - INFORM DOCTOR
  - Give feed if able to tolerate, if not intravenous maintenance fluids, 10% dextrose + saline (e.g. 10% dextrose/0.45% saline)
  - Recheck finger prick BG every 15 min until glucose >4.0mol/L
  - If BG remains low consider further bolus and increase dextrose concentration/ fluid rate (INFORM DOCTOR)
  - CONTACT METABOLIC/ENDOCRINE CONSULTANT ON CALL IF ANY CONCERNS

Protocol
Duration:

<table>
<thead>
<tr>
<th>AGE</th>
<th>&lt;6 mo</th>
<th>6-8 mo</th>
<th>8-12 mo</th>
<th>1-2 yr</th>
<th>2-7 yr</th>
<th>&gt;7 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>DURATION</td>
<td>8 hr</td>
<td>12 hr</td>
<td>16 hr</td>
<td>18 hr</td>
<td>20 hr</td>
<td>24 hr</td>
</tr>
</tbody>
</table>

Note: These times are for guidance only; hypoglycaemia may develop earlier, particularly if there is an underlying disorder. Please confirm the length of fast with either the metabolic/endocrine team. Careful monitoring of blood glucose is essential throughout the fast. Please record the patient’s clinical condition during the fast in his/her notes. This protocol is for a 12 hour fast (other protocols are available for fasts of different lengths).

- The child should be admitted at around 4 pm on a weekday (not Friday). The child should be clerked in by a member of the endocrine/metabolic team and all blood and urine forms should be printed off at the start of the fast.

- The fast should normally start at 10 pm (after supper/snack) and aim to end at 10 am on the following day. This minimises the risk of hypoglycaemia during the night and allows the collection of the majority of samples when the endocrine/metabolic team is present and when the laboratories are open. Adequate handover should be given to the on call team for the risk of hypoglycaemia and if inadvertently the fast ends after 5 pm. The timing of the fast may need to be reviewed if children are usually unable to go through the night without additional food.

- The patient should stay for 4-6 hours after fast is completed to ensure they remain well and there are no hypoglycaemic episodes. If necessary, an additional overnight stay may be needed to ensure clinical stability.

- Finger prick blood glucose should be monitored by a ward bedside monitor hourly throughout the duration of the fast. If BG < 3.0 mmol/L, check again in 15 minutes. If BG < 2.6mmol/L or if the child is symptomatic of hypoglycaemia (feels hot, sweaty, flushed, tachycardia, decreasing consciousness), a venous sample for glucose and other hypoglycaemic screen bloods should be taken immediately and hypoglycaemia treated as above. At the same time ketones should be measured on the ward blood glucose meter.
Samples

Arrange bottles prior to test and also inform on-call biochemist (x12233). All sample bottles are available as part of a hypoglycaemia testing pack available from Biochemistry. Check the nearest source of ice and ensure availability at the time of hypoglycaemia. Insert the largest possible venous cannula at the start of the fast. Collect blood samples as shown below. All bottles must have the date and time of sample collection recorded.

The samples are listed in order of priority, the most important being Glucose/Lactate, Insulin/C-peptide and FFAs.

<table>
<thead>
<tr>
<th>Blood Samples</th>
<th>Time (hr)</th>
<th>0</th>
<th>4</th>
<th>8</th>
<th>10</th>
<th>12+</th>
<th>1 hr post fast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedside Blood Glucose/ketones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 mL yellow (discuss with biochemistry lab before sending)</td>
<td>Glucose/Lactate</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>1 mL heparinised (orange), to biochemistry lab immediately on ice</td>
<td>Insulin/C-peptide</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 mL heparinised (orange), to biochemistry lab immediately on ice</td>
<td>3 OH butyrate/FFA</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood spot cards (or 1mL heparinised sample) to Willink Lab</td>
<td>Acylcarnitines</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1mL (plastic EDTA)* RED TOP (to biochemistry lab immediately, on ice)</td>
<td>Ammonia</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Capillary tube</td>
<td>Venous Gas</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 mL clotted (white) to biochemistry lab</td>
<td>Growth hormone/Cortisol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

*special tube required for Ammonia sample (please check availability before starting fast)
+at end of fast or at time of hypoglycaemia

Urine samples:

<table>
<thead>
<tr>
<th>Organics acids &amp; amino acids</th>
<th>Collect aliquots of all urine passed from beginning of fast till 4 hours after end of fast</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10 ml in a sterile container</td>
<td></td>
</tr>
</tbody>
</table>

Glucagon Test

*Only To Be Performed If Requested By The Endocrine Team.*

- Once fast is completed and there is no evidence of hypoglycaemia: administer 0.03 mg/kg (maximum 1 mg) of Glucagon i.m..
- Blood glucose should be measured at 0, 5, 15, 30, 45, 60 and 90 minutes; Blood lactate should be measured at 0, 30, 60 and 90 minutes

Interpretation of glucagon test

Normal children will exhibit a rise in BG of 2 mmol/L. There is an exaggerated response in children with hyperinsulinism.

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Management of hypoglycaemia

If at any time during the fast the child becomes hypoglycaemic with bedside finger prick glucometer reading ≤ 2.6 mmol/L (but remember blood glucose [BG] levels are inaccurate at low levels) or if symptomatic, do the following without delay:

- take blood samples as listed as for the end of the fast (12 hours) and
- stop the fast immediately after the blood has been taken.
  - If symptomatic, give glucose (3 mL/kg of i.v. 10% Dextrose) - INFORM DOCTOR
  - Give feed if able to tolerate, if not intravenous maintenance fluids, 10% dextrose + saline (e.g. 10% dextrose/0.45% saline)
  - Recheck finger prcik BG every 15 min until glucose >4.0mol/L
  - If BG remains low consider further bolus and increase dextrose concentration/ fluid rate (INFORM DOCTOR)
  - CONTACT METABOLIC/ENDOCRINE CONSULTANT ON CALL IF ANY CONCERNS

Protocol

Duration:

<table>
<thead>
<tr>
<th>AGE</th>
<th>&lt;6 mo</th>
<th>6-8 mo</th>
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<tr>
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<td>12 hr</td>
<td>16 hr</td>
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<td>24 hr</td>
</tr>
</tbody>
</table>

- Note: These times are for guidance only; hypoglycaemia may develop earlier, particularly if there is an underlying disorder. Please confirm the length of fast with either the metabolic/endocrine team. Careful monitoring of blood glucose is essential throughout the fast. Please record the patient’s clinical condition during the fast in his/her notes. This protocol is for an 18 hour fast (other protocols are available for fasts of different lengths).

- The child should be admitted at around 4 pm on a weekday (not Friday). The child should be clerked in by a member of the endocrine/metabolic team and all blood and urine forms should be printed off at the start of the fast.

- The fast should normally start at 6 pm (after dinner) and aim to end at 12 noon on the following day. This minimises the risk of hypoglycaemia during the night and allows the collection of the majority of samples when the endocrine/metabolic team is present and when the laboratories are open. Adequate handover should be given to the on call team for the risk of hypoglycaemia and if inadvertently the fast end after 5 pm. The timing of the fast may need to be reviewed if children are usually unable to go through the night without additional food.

- The patient should stay for 4-6 hours after fast is completed to ensure they remain well and there are no hypoglycaemic episodes. If necessary, an additional overnight stay may be needed to ensure clinical stability.

- Finger prick blood glucose should be monitored by a Nova ward bedside monitor hourly throughout the duration of the fast. If BG < 3.0 mmol/L, check again in 15 minutes. If BG <2.6mmol/L or if the child is symptomatic of hypoglycaemia (feels hot, sweaty, flushed, tachycardia, decreasing consciousness), a venous sample for glucose and other hypoglycaemic screen bloods should be taken immediately and hypoglycaemia treated as above. At the same time ketones should be measured on the ward blood glucose meter.
Samples
Arrange bottles prior to test and also inform on-call biochemist (x12233). All sample bottles are available as part of a hypoglycaemia testing pack available from Biochemistry. Check the nearest source of ice and ensure availability at the time of hypoglycaemia. Insert the largest possible venous cannula at the start of the fast. Collect blood samples as shown below. All bottles must have the date and time of sample collection recorded.

The samples are listed in order of priority, the most important being Glucose/Lactate, Insulin/C peptide and FFAs.

<table>
<thead>
<tr>
<th>Blood Samples</th>
<th>Time (hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Bedside Blood glucose/ketones</td>
<td>1 hr hourly monitoring from time of stopping feeds: ketones when/if hypoglycaemia occurs and at end of fast</td>
</tr>
<tr>
<td>1 mL yellow (discuss with biochemistry lab before sending)</td>
<td>Glucose/Lactate</td>
</tr>
<tr>
<td>1 mL heparinised (orange), to biochemistry lab immediately on ice</td>
<td>Insulin/C-peptide</td>
</tr>
<tr>
<td>1 mL heparinised (orange), to biochemistry lab immediately on ice</td>
<td>3 OH butyrate/FFA</td>
</tr>
<tr>
<td>Blood spot cards (or 1mL heparinised sample) to Willink Lab</td>
<td>Acylcarnitines,</td>
</tr>
<tr>
<td>1mL (plastic EDTA)* RED TOP (to biochemistry lab immediately, on ice)</td>
<td>Ammonia</td>
</tr>
<tr>
<td>Capillary tube</td>
<td>Venous Gas</td>
</tr>
<tr>
<td>2 mL clotted (white) to biochemistry lab</td>
<td>Growth hormone/ Cortisol</td>
</tr>
</tbody>
</table>

*special tube required for Ammonia sample (please check availability before starting fast)
+at end of fast or at time of hypoglycaemia

Urine samples:
| 5-10 mL in a sterile container | Organic acids & amino acids | Collect aliquots of all urine passed from beginning of fast till 4 hours after end of fast |

Glucagon Test
Only To Be Performed If Requested By The Endocrine Team.

- Once fast is completed and there is no evidence of hypoglycaemia: administer 0.03 mg/kg (maximum 1 mg) of Glucagon i.m..
- Blood glucose should be measured at 0, 5, 15, 30,45, 60 and 90 minutes; Blood lactate should be measured at 0, 30, 60 and 90 minutes

Interpretation of glucagon test
Normal children will exhibit a rise in BG of 2 mmol/L. There is an exaggerated response in children with hyperinsulinism.

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Royal Manchester Children's Hospital
20 Hour Controlled Fast

**Please discuss with Metabolic/Endocrine Team before carrying out this test. This fast is designed primarily for the use of the Metabolic and Endocrine teams at RMCH. All patients, prior to any fasting studies, should have been assessed and fat oxidation disorders, such as MCAD deficiency, excluded by appropriate investigations.**

**Management of hypoglycaemia**

If at any time during the fast the child becomes hypoglycaemic with bedside finger prick glucometer reading \( \leq 2.6 \text{ mmol/L} \) (but remember blood glucose [BG] levels are inaccurate at low levels) or if symptomatic, do the following without delay:

- take blood samples as listed as for the end of the fast (12 hours) and
- stop the fast immediately after the blood has been taken.
  - If symptomatic, give glucose (3 mL/kg of i.v. 10% Dextrose) - INFORM DOCTOR
  - Give feed if able to tolerate, if not intravenous maintenance fluids, 10% dextrose + saline (e.g. 10% dextrose/0.45% saline)
  - Recheck finger prick BG every 15 min until glucose >4.0 mmol/L
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- The child should be admitted at around **2 pm** on a weekday (not Friday), after lunch. The child should be clerked in by a member of the endocrine/metabolic team and all blood and urine forms should be printed off at the start of the fast.

- The fast should normally start at **2 pm** (after lunch) and aim to end at **10 am** on the following day. This minimises the risk of hypoglycaemia during the night and allows the collection of the majority of samples when the endocrine/metabolic team is present and when the laboratories are open. Adequate handover should be given to the on call team, for the risk of hypoglycaemia and if inadvertently the fast ends after 5 pm. The timing of the fast may need to be reviewed if children are usually unable to go through the night without additional food.

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<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20+</th>
<th>1 hr post fast</th>
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<tbody>
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<td>Bedside Blood glucose/ketones</td>
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**Tubular Reabsorption of Phosphate**

**CWS Test Name:** TmP/GFR

**Principle**
Many factors affect the renal tubular reabsorption of phosphate including PTH, diet, ECF volume, acid-base status. Calculation of the ratio of the renal tubular maximum reabsorption rate of phosphate to glomerular filtration rate (TmP/GFR) is much more useful than measurement of urine phosphate alone. It is independent of GFR and has replaced earlier indices of renal phosphate handling (phosphate excretion index).

**Indication**
- Investigation of persistent unexplained hypophosphataemia or assessment of renal tubular function.

**Precautions**
- None

**Side Effects**
- N/A

**Preparation**
- The test should ideally be carried out in the morning, after an overnight fast, as there is a significant diurnal variation.
- Stop phosphate supplements prior to the test.

**Protocol**
1. After waking the patient should empty the bladder – discard urine. The patient may drink water during the test.
2. Collect the next urine passed and send to the lab straight away for acidification. Record the time of collection.
3. Collect a blood sample for phosphate and creatinine (1 mL Lithium Heparin – orange top) and record the time of collection. The blood must be collected within 2 hours of the urine sample. Capillary samples are unsuitable due to the effect on phosphate concentration.

**Samples**
- **Phosphate and Creatinine**
  - 1 mL lithium heparin (orange top)

**Interpretation**

**Calculation of TmP/GFR in children**

\[
\text{TmP/GFR} = \frac{P_{\text{phosphate}}}{\text{U}_{\text{phosphate}}} - \left( \frac{U_{\text{phosphate}} \times P_{\text{creatinine}}}{U_{\text{creatinine}}} \right)
\]

\(P =\) plasma concentration \(U = \) urine concentration

All concentrations in mmol/L

<table>
<thead>
<tr>
<th>Age</th>
<th>TmP/GFR in mmol/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborns</td>
<td>1.55 – 2.97</td>
</tr>
<tr>
<td>1 month – 2 yrs</td>
<td>1.07 – 2.23</td>
</tr>
<tr>
<td>2 - 12 yrs</td>
<td>1.10 – 1.88</td>
</tr>
<tr>
<td>12 - 16 yrs</td>
<td>0.93 – 1.71</td>
</tr>
<tr>
<td>&gt;16 yrs</td>
<td>0.88 – 1.26</td>
</tr>
</tbody>
</table>

In general, when hyperphosphataemia is due to increased phosphate flow from gut, cells or bone there is a decrease in TmP/GFR i.e. a decrease in phosphate reabsorption. Hypophosphataemia due to decreased phosphate flow results in an increased TmP/GFR.
A decreased TmP/GFR is found in hypophosphataemia due to renal tubular dysfunction e.g. Fanconi syndrome, X-linked hypophosphataemic rickets. There is also a renal component to the hypophosphataemia which can follow glucose infusion/refeeding after starvation and respiratory alkalosis, leading to a decreased TmP/GFR, despite a decrease in phosphate flow. Hyperparathyroidism (primary and secondary) can also cause a decrease in TmP/GFR.

**Note on use in adults**

N.B. Use of this formula in adults may require a correction factor, α, when the TRP is ≥0.86.

\[
\text{TRP} = 1 - (\text{Uphosphate} \times \text{Pcreatinine/ Pphosphate} \times \text{Ucreatinine})
\]

If TRP ≥0.86 then:
\[
\alpha = 0.3 \times \frac{\text{TRP}}{1 - (0.8 \times \text{TRP})}
\]

\[
\text{TmP/GFR} = \alpha \times \text{Pphosphate}
\]

If TRP <0.86 then:
\[
\text{TmP/GFR} = \text{TRP} \times \text{Pphosphate} \quad \text{(mathematically the same as the equation on the previous page)}.
\]

**References**