### Management of Fluid and Electrolytes in Neonates D2 (prev.D14)

<table>
<thead>
<tr>
<th>Title of Guideline (must include the word “Guideline” (not protocol, policy, procedure etc)</th>
<th>Author: Contact Name and Job Title</th>
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</thead>
<tbody>
<tr>
<td><strong>Nottingham Children’s Hospital</strong></td>
<td>Version 3: Dr. Ai May Lee, Dr. Stephen Wardle Adapted version 2 Dr. Katherine Millard, Dr. Stephen Wardle</td>
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<thead>
<tr>
<th>Directorate &amp; Speciality</th>
<th>Neonatal Intensive Care Unit, Family Health</th>
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<tr>
<th>Explicit definition of patient group to which it applies (e.g. inclusion and exclusion criteria, diagnosis)</th>
<th>New born infants born in Nottingham who fit the inclusion criteria of the guideline below</th>
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<table>
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<tr>
<th>Version</th>
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<tr>
<th>If this version supersedes another clinical guideline please be explicit about which guideline it replaces including version number.</th>
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<tr>
<th>Statement of the evidence base of the guideline – has the guideline been peer reviewed by colleagues?</th>
<th>2,3,4 (Please also see page 9)</th>
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<table>
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<tr>
<th>Evidence base: (1-6)</th>
<th>Nottingham Neonatal Intensive Care Unit Staff, Nottingham Regional Paediatric Nephrology, wider consultation during neonatal grand round meeting April 2017</th>
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<table>
<thead>
<tr>
<th>1</th>
<th>NICE Guidance, Royal College Guideline, SIGN (please state which source).</th>
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<table>
<thead>
<tr>
<th>2a</th>
<th>meta analysis of randomised controlled trials</th>
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<tr>
<th>2b</th>
<th>at least one randomised controlled trial</th>
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<th>3a</th>
<th>at least one well-designed controlled study without randomisation</th>
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<th>3b</th>
<th>at least one other type of well-designed quasi-experimental study</th>
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<th>4</th>
<th>well –designed non-experimental descriptive studies (ie comparative / correlation and case studies)</th>
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<tr>
<th>5</th>
<th>expert committee reports or opinions and / or clinical experiences of respected authorities</th>
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<tr>
<th>6</th>
<th>recommended best practise based on the clinical experience of the guideline developer</th>
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<tr>
<th>Consultation Process</th>
<th>Nottingham Neonatal Service Guideline Task and Finish Group</th>
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<tr>
<th>Ratified by:</th>
<th>May 2017</th>
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<tr>
<th>Review Date: (to be applied by the Integrated Governance Team)</th>
<th>Staff of the Nottingham Neonatal Service and Labour wards at QMC and City Campus, Paediatrics</th>
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<tr>
<th>A review date of 5 years will be applied by the Trust. Directorates can choose to apply a shorter review date, however this must be managed through Directorate Governance processes.</th>
<th>May 2022</th>
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</table>
1. Introduction / Background

During the first few days after birth all babies lose weight due to loss of extra-cellular fluid. This diuresis and loss of weight is associated with cardiopulmonary adaptation; it occurs rapidly in healthy babies but may be delayed in those with respiratory distress syndrome. As extra-cellular fluid is lost there is a net loss of both water and sodium, although serum sodium should remain within the normal range. The normal infant should lose up to 10% of its birth weight. This weight loss is physiological and should be expected. In general normal healthy infants are not weighed during this period and this weight loss is therefore not recognised.

The calculation of fluid and electrolyte requirements is based on the daily maintenance of water, sodium and potassium intakes. However the needs of preterm infants differ from those of term infants due to immature renal function and less efficient mechanisms for sodium homeostasis, which may lead to high baseline losses. Preterm infants have very large insensible losses mainly due to loss of fluid through the immature skin and because of a larger surface area to weight ratio. The amount of water loss rises exponentially with lower gestational age. In addition preterm infants are frequently unwell and have other complications or are receiving drugs that affect fluid and electrolyte balance. Fluid balance therefore needs to take account of the baby’s prematurity and the severity of the congenital or acquired disorder.

2. Patient Groups

Infants receiving any IV fluids as part of their neonatal care including preterm infants, sick term infants and infants with surgical problems. The volume of milk given to infants receiving enteral feeds is covered in Neonatal Guideline D3 (Introducing and advancing enteral feeds), and therefore this guideline should not be used to determine the volume of enteral feed a baby receives.

3. Management

3.1 Type of fluids

Preterm infants < 30 weeks gestation / <1000g should be commenced on starter PN (see Neonatal Guideline D6 Neonatal Parenteral Nutrition) via a central line (UVC or percutaneous long line)

For all other infants requiring IV fluids

Day 1-2  10% dextrose

Day 3  10% dextrose / 0.18% saline if the baby's urea and electrolytes remain within the normal limits.

For all surgical infants or preterm infants who have not received feeds by day 3 the use of PN should be considered rather than 10% dextrose / 0.18% saline (see Neonatal Guideline D6 Neonatal Parenteral Nutrition [PN]).
3.2 Assessment of fluid balance

This requires knowledge of:

<table>
<thead>
<tr>
<th>1. Weight</th>
<th>measured daily in infants receiving level 1 (intensive) care Should be a steady loss of 1-2% per day until day 7</th>
</tr>
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<tbody>
<tr>
<td>2. Serum sodium</td>
<td>infants &lt; 1000g at least twice daily days 1-3 infants &gt; 1000g at least daily whilst receiving intensive care</td>
</tr>
<tr>
<td>3. Urine output and any other losses</td>
<td>assessed continuously whilst receiving intensive care. Review 8 hourly Should be 1-4 ml / kg / hour. Abnormal if &lt; 1ml / kg / hour</td>
</tr>
<tr>
<td>4. Fluid input</td>
<td>assessed continuously</td>
</tr>
<tr>
<td>5. Serum creatinine</td>
<td>measured daily for infants receiving intensive care Should fall exponentially after birth</td>
</tr>
<tr>
<td>6. Urine specific gravity and urinalysis</td>
<td>Measured daily in infants receiving level 1-2 care</td>
</tr>
</tbody>
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3.3 Rates of Fluid Input

Summary of Evidence

Several studies have tried to assess whether ‘high’ or ‘low’ rates of fluid input have advantages during the first few days after birth in preterm infants. These are summarised in a systematic review and meta-analysis on the Cochrane Database [1]. Unfortunately the five studies included in the 2010 update are all different in the fluid regimens that they have used and the infants included in the studies however in summary the meta-analysis shows that restricted water intake significantly reduces the risks of PDA and NEC. There are trends towards reduced risks of bronchopulmonary dysplasia, intracranial haemorrhage and death, but these trends are not statistically significant. On the basis of this careful restriction of water intake so that physiological needs are met without allowing significant dehydration appears the most sensible policy. Unfortunately however the volume of fluid necessary to achieve this is not clear and therefore needs to be assessed individually for each baby.

3.3.1 Management of Fluid Balance

During the first 5 days after birth there is no set amount of fluid that should be given to particular infants on each day. It should be assessed on an individual basis. IV fluids should be started at 60 ml/kg/day (40mls/kg/day for term infants) and then in general assess fluid balance at least daily (at least twice daily for infants < 1000g).

The other factors listed above should also be taken into account – urine output, fluid balance and serum creatinine including trends in changes in weight and serum sodium as well as actual values on any particular day.

Adjust the fluid input according to assessment:-

<table>
<thead>
<tr>
<th>Sodium</th>
<th>Change in weight (compared to most recent)</th>
<th>Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Decreased</td>
<td>Increase fluid input. Do not decrease sodium input</td>
</tr>
<tr>
<td>High</td>
<td>Increased</td>
<td>Decrease sodium and fluid input</td>
</tr>
<tr>
<td>High</td>
<td>Daily decrease &lt;3%</td>
<td>Continue same fluid / sodium input</td>
</tr>
<tr>
<td>Low</td>
<td>Daily decrease &lt;3%</td>
<td>Increase sodium input</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Low</td>
<td>Daily decreased &gt;3%</td>
<td>Increase fluid and sodium input</td>
</tr>
<tr>
<td>Normal / low</td>
<td>Increased</td>
<td>Decrease fluids.</td>
</tr>
<tr>
<td>Normal</td>
<td>Daily decreased &gt;3%</td>
<td>Increase fluid input</td>
</tr>
<tr>
<td>Normal</td>
<td>Daily decrease &lt;3%</td>
<td>Continue same fluids / sodium input</td>
</tr>
</tbody>
</table>

Remember this is a guideline and the decision about how much fluid to prescribe can be a complicated one when all these factors must be considered.

As a rough guide the following may be useful to aim for but should not be used without daily assessment particularly in babies < 1000g:

<table>
<thead>
<tr>
<th>Day after birth</th>
<th>Fluid requirement per day</th>
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<tbody>
<tr>
<td>1</td>
<td>60 ml/kg</td>
</tr>
<tr>
<td>2</td>
<td>70 ml/kg</td>
</tr>
<tr>
<td>3</td>
<td>80 ml/kg</td>
</tr>
<tr>
<td>4</td>
<td>90 ml/kg</td>
</tr>
<tr>
<td>5</td>
<td>120 ml/kg</td>
</tr>
</tbody>
</table>

- For most infants receiving IV fluids alone there is generally no reason to exceed 120 ml / kg / day but this needs to be assessed individually for each infant.
- In very small infants (<1000g) larger fluid volumes may be required because of high losses.

### 3.3.2 Which weight to use
- The birthweight should be used in the calculation of fluid balance, until this has been regained (around day 10) when subsequently the highest weight is used unless there has been oedema and fluid overload. In the case of severe hydrops or water overload, an estimated weight may have to be used (50th centile for corrected gestational age).

### 3.3.3 Daily weight
- Weight is the most adequate way of assessing water balance over the first few days, especially in the very preterm infant who is experiencing transcutaneous water losses. Daily weights therefore provide a guide to the adequacy of fluid replacement and should therefore be done in all but the most unstable babies receiving intensive care.

### 3.3.4 Other infusions
- Arterial fluid solutions and many infused drugs contribute to the volume and may also contain sodium and chloride and should be considered in all fluid calculations. Drugs and fluids should always be counted in the assessment of fluid input. For example a 500g infant with an arterial line running at 0.5ml/hr of 0.45% saline who has 6 blood gases in a day (each with 1ml flush) will receive (from this source alone) 3.6 mmol/kg/day of sodium and chloride.
- Colloid infusions (human albumin, fresh frozen plasma and blood) also contain a considerable amount of sodium and chloride.

### 3.3.5 Hypoglycaemia
In the presence of hypoglycaemia rates of infusions may need to be altered (see Neonatal Guideline D1 Screening & management of neonatal hypoglycaemia)
3.3.6 Renal function
- Where there is prolonged oliguria careful management is needed. See Neonatal Guideline D19 Management of acute renal impairment and discuss with Consultant.
- Creatinine is the most useful indicator of renal function in the newborn and should be measured every day in the sick newborn (in the first 24 hours the serum creatinine will reflect the mother's renal function).
- Urea concentration may be variable and high in preterm infants as a result of catabolism. So a high blood urea in a sick baby does not always indicate dehydration or renal failure. The measurement of urea is therefore less useful although it tends to be done with the Creatinine and electrolytes.

3.3.7 Increased non-renal losses
- Gastric aspirates and stoma losses should be measured accurately and are usually replaced ml for ml with appropriate fluid, e.g. 0.9% saline with 10 mmol potassium chloride in 500ml. In general this is only required if losses exceed 20 ml/kg/day, but this may be altered at the discretion of the surgical team in conjunction with the Consultant Neonatologist. Protein rich losses such as chyle, CSF, abdominal paracentesis, may need to be replaced with an appropriate colloid (4.5% albumin solution) if losses >20 ml/kg, or if there is a low serum albumin.

4. Electrolytes

4.1 Sodium
Sodium is usually excreted via the kidney, controlled by the renin-angiotension-aldosterone system. This control mechanism is as active in the preterm as in the term infant, but tubular unresponsiveness leads to sodium wastage at low gestations and in the sick newborn.

In general additional sodium is not required until there has been a post-natal diuresis which normally occurs around day 2-3. Therefore sodium is not added to IV fluids until day 3. Care should be given to controlling the amount of sodium babies receive from other sources before this (flushes, arterial infusions etc.).

From day 3 onwards normal sodium requirements are 1-2 mmol/kg/day for term infants and 3-5 mmol/kg/day in the well preterm, but the very preterm needs may be higher secondary to tubular losses and preterm infants may need as much as 12-15 mmol/kg/day.

4.1.1 Hyponatraemia (plasma sodium <130 mmol/l)

Causes
Water overload (commonest cause in the first week in the preterm infant)
- In the first 24 hours may be due to excess fluids being administered to the mother prior to delivery.
- Excessive administration of fluid
- Secondary to ADH secretion
- Acute renal failure in the oliguric phase before fluid restriction

Increased sodium loss
- Excessive renal loss in the preterm infant (especially during illness, diuretic or methylxanthiane therapy)
- Excessive bowel sodium loss during obstruction or occasionally infection and particularly in babies with stomas especially those which are higher (ileostomy / jejunostomy).
- Rarely inherited tubular disorders or adrenal insufficiently (with low potassium and water loss)

Inadequate sodium intake
- During IV fluid therapy / IV feeding
- During oral feeding with unsupplemented breast milk or term formula in the preterm infant
- It may be helpful to measure urinary sodium losses as fractional sodium excretion

$$\text{FeNA} = \frac{\text{Urine Na} \times \text{Plasma Creatinine} \times 100}{\text{Urine creatinine \ Plasma Na}}$$

- Carefully check the units of creatinine to ensure urine and plasma are in the same units
Nottingham Neonatal Service - Clinical Guidelines  

- Normal FeNa is <1% in healthy term babies, but values may be up to 16% in the sick preterm due to renal sodium wasting, without implying renal failure.

**Management of hyponatraemia**

**Prevention**

Anticipate situations when losses may be high, such as in the very preterm or following bowel surgery. Maintain strict fluid balance records and replace losses as appropriate.

**Treatment (plasma sodium <130)**

Determine the cause by assessing the baby’s sodium, change in weight (see above) and FeNa. Note that the trend in changes in sodium is as important as the actual value.

Then either restrict fluids if fluid overload is suspected or give additional sodium (see pharmacy file for administration)

4.1.2 **Hypernatraemia** (plasma sodium >145 mmol/l)

**Causes**

- Transepidermal water loss in the very preterm infant
- Excessive fluid loss with vomiting, diarrhoea or bowel obstruction (although both water and sodium are usually lost)
- Glycosuria may cause an osmotic diuresis in a very sick or preterm infant

**Management**

If no circulatory compromise, rehydrate slowly over 24-48 hours either orally or using isotonic solutions (0.9% sodium chloride).

**Excessive sodium**

- Incorrect fluid prescription
- Excessive amount of sodium bicarbonate prescribed
- Use of other medications with a high sodium content

**Management** - Restrict sodium intake
- Congenital hyperaldosteronism (very rare)
  **Management** - Give diuretic (spironolactone), discuss with Paediatric Endocrinologist.

4.2 **Potassium**

Renal excretion and conservation are similarly well developed in the newborn. Plasma concentrations are buffered because the majority (90%) is intracellular, so a low plasma concentration is a late sign of whole body depletion.

- Breast milk contains about 1 mmol/kg/day
- A sick neonate with normal renal function will require 2-3 mmol/kg/day to maintain a positive balance
- If there is acute renal failure, oliguria or high potassium levels, potassium replacement should be withheld.

4.2.1 **Hypokalaemia** (Plasma potassium <3.5 mmol/l)

**Causes**

- Inadequate intake – potassium supplements may have to be added to IV fluids after the first 48 hours unless urine output is poor
- Gastrointestinal losses from vomiting, diarrhoea, nasogastric or stoma
- Alkalosis (buffering of pH causes renal potassium wastage)
- Diuretics all cause potassium wastage, particularly loop diuretics, e.g. frusemide.
- Hyperaldosteronism.
- Hypomagnesaemia may be associated with hypokalaemia and may need correcting
Clinical signs
- Cardiac dysrhythmia (ECG changes include a decreased T wave and ST depression)
- Ileus

Management
- Increase potassium intake in infusion fluid or give oral supplements. Baseline requirement 1-3 mmol/kg/day. Be vigilant in checking calculations of potassium supplements to IV bags.
- For administration see pharmacy file.

4.2.2 Hyperkalaemia (Plasma potassium >7 mmol/l)

Hyperkalaemia poses a significant risk, including predisposing to cardiac arrhythmias by causing a decrease in membrane resting potential, increasing membrane excitability.

Acute kidney injury can result in hyperkalemia due to impaired renal excretion, and this can be exacerbated by metabolic acidosis. In acidosis, hydrogen ions move from the plasma into cells to buffer the intravascular pH, then to maintain electro-neutrality, potassium moves out of the cell resulting in hyperkalaemia.

Clinical signs

ECG changes that may be seen with hyperkalaemia include:
- Tall, peaked T waves
- Prolonged PR interval
- Flattened P wave
- Wide QRS,
- Refractory hyperkalaemia may cause progressive changes leading to SVT, ventricular fibrillation or asystole and death.

Management

Life-threatening cardiac arrhythmias
Full 'ABC' resuscitation, including cardioversion in refractory arrhythmias

If potassium >6mmol/L but < 7mmol/L

Apparent hyperkalemia can be caused by sample haemolysis, therefore ensure that you repeat an urgent free-flowing venous or arterial sample.

Discontinue medication and fluids containing potassium and discuss with a consultant before giving any blood products as these can contain high levels of potassium. Investigate the cause of the hyperkalaemia.

It is useful to perform a 12 lead ECG: if ECG changes are present treat according to K+>7 protocol.

Monitor potassium at least 2 hourly, ensure the baby is on a cardiac monitor.

If potassium >7

Confirm if this is a true reading by repeating a free-flowing sample.

Discontinue medication and fluids containing potassium and discuss with a consultant before giving any blood products as these can contain high levels of potassium. Investigate the cause of the hyperkalaemia.

Ensure baby is on a cardiac monitor, perform a 12 lead ECG but do not let the logistics of this delay treatment.

**Discuss with Consultant on call**
Consider instituting some of the treatments outlined below.

- **Calcium gluconate** IV 10% 0.5 ml / kg over 4 mins (helps to prevent arrhythmias by increasing membrane resting potential, does not directly affect potassium levels). This can be given promptly after hyperkalaemia is diagnosed, but it only lasts for 30-60 minutes so more definitive methods of reducing serum potassium are required.

- **Bicarbonate**: Half correct the acidosis with sodium bicarbonate (this will drive potassium back into the cells, reducing plasma levels for up to 2 hours, and will improve cardiac function)- be careful as this can cause hypocalcaemia (precipitating arrhythmia) and cause volume overload to worsen.

- **Salbutamol**: 4 micrograms / kg IV bolus over at least 5 minutes. Drives potassium intracellularly by 1-1.5mmol/l per dose with effects lasting up to 2 hours and doses may be repeated as required.

- **Furosemide**: Increases potassium excretion, but only in the presence of urine output.

- **Calcium resonium**: Not to be used routinely and to be discussed with consultant on call before use. Rectally to provide longer-term background removal of potassium, 125-250mg/kg PR 6-8 hourly. Can cause rectal plugs, intestinal obstruction and necrosis in the neonate, and takes several hours to be effective.

- **Dextrose / insulin infusion** can be used to drive potassium intracellularly but is less safe than salbutamol. Add 2.5 units actrapid insulin to 50ml glucose 10% giving a solution of 1 unit / 2g glucose. Infuse at 0.05 – 0.1units/kg/hr (1-2ml/kg/hr) and monitor blood glucose carefully (see pharmacy file for more detailed information). Check blood glucose every 30-60 minutes initially and adjust glucose concentration accordingly.

### 4.3 Calcium and Magnesium

Serum calcium levels appear low in the newborn because of low albumin levels. There is a normal physiological fall in calcium concentrations after birth, which rises after the second day.

#### 4.3.1 Hypocalcaemia (Corrected calcium <1.5 mmol / l)

**Causes**
- Encephalopathy
- Renal failure.
- Di George syndrome
- Disordered maternal calcium metabolism
- Maternal diabetes mellitus

**Management**
- Early hypocalcaemia rapidly resolves on milk or parenteral feeding
- Symptomatic hypocalcaemia-tetany seizures is rare with modern milks
- If treatment is needed, a slow infusion (over 10 minutes) of 0.2 mmol/kg (1 ml/kg 10% calcium gluconate) is given, observing the infusion site carefully for extravasation and with ECG monitoring.
- See pharmacy file for more detail about administration.
- See Neonatal Guideline E2, Monitoring and Management of Hypotension / Cardiovascular Support in Neonates, for management of a low ionised calcium in babies with cardiovascular compromise.

#### 4.3.2 Hypercalcaemia (Calcium >2.8 mmol/l)

**Cause**
- Phosphate deficiency in the very preterm
- Prolonged calcium infusions without additional phosphate
- Over-treatment with vitamin D

**Management**
Discontinue causative therapy or additional phosphate therapy
4.3.3 Hypomagnesaemia
A low magnesium may accompany hypocalcaemia. Magnesium levels should be checked during investigation of seizures or if a low calcium persists despite treatment.

**Management**
Magnesium can be given IV or IM 100 mg/kg (0.4 mmol/kg), (see pharmacy file for more detailed information). Oral therapy is sometimes used in chronic malabsorption states but causes diarrhoea.

4.4 Phosphate

**Hypophosphataemia**

**Cause**
- Prematurity

Additional phosphate supplements may sometimes be required in preterm infants. For infants on PN this can usually be given in the PN. For infants on oral feeds, preterm formula and EBM with BMF should contain sufficient phosphate but if not then oral supplements can be given in the form of potassium dihydrogen phosphate (see Neonatal Guideline D11 Metabolic bone disease in preterm infants). IV supplementation may sometimes be required for the infant who is not on PN or where the PN phosphate is already maximised. See pharmacy information folder for dose and administration details.

5. Audit Points

6. Allied Guidelines
Neonatal Guideline D1 Screening & management of neonatal hypoglycaemia
Neonatal Guideline D3 Introducing and advancing enteral feeds
Neonatal Guideline D4 Enteral nutrition and feeding of preterm infants
Neonatal Guideline D6 Neonatal parenteral nutrition (PN)
Neonatal Guideline D19 Management of acute renal impairment

References

### Summary Box and Levels of Evidence

<table>
<thead>
<tr>
<th>Summary</th>
<th>Level of evidence</th>
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<tbody>
<tr>
<td>Limiting the rate of fluid input to that required for physiological needs may decrease PDA and NEC [1]</td>
<td>A</td>
</tr>
<tr>
<td>Fluid assessment requires at least daily assessment of weight and serum sodium</td>
<td>C</td>
</tr>
<tr>
<td>Infants &lt; 1000g require more frequent assessment of creatinine and electrolytes</td>
<td>C</td>
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</tbody>
</table>