Background: A study was undertaken to ascertain whether systemic eosinophil activation is associated with preschool viral wheeze (PVW).

Methods: Urinary eosinophil protein X (uEPX) and serum total IgE (IgE) levels were measured in children admitted to hospital with PVW, and uEPX was measured 6 weeks after discharge. Two years after admission, current wheeze in children aged ≥5 years was determined by questionnaire. Controls were recruited from children undergoing elective surgery (normal controls) and from those with skin prick test reactivity to foods (atopic controls).

Results: There was no difference in uEPX levels between normal controls (n=15) and atopic controls (n=8). uEPX levels were increased in children with acute PVW (n=84; p<0.001 v normal controls, p<0.01 v atopic controls) and fell on convalescence (n=20, 95% CI –217 to –31 μg/mmol creatinine, p<0.05). In children with acute PVW there was no association between uEPX and serum IgE levels or markers of clinical severity. Respiratory questionnaires were returned for 25/55 eligible children. There was no difference in uEPX level during acute PVW when stratified by ‘current wheeze’ (n=18) or ‘no wheeze’ (n=7) 2 years later.

Conclusions: Systemic eosinophil activation is associated with PVW but is not associated with serum IgE, clinical severity, or persistence of wheeze into the early school age period.
blood sample was obtained for serum IgE and blood eosinophil measurement. The number of nebulised bronchodilators during the admission and the total duration of the illness was recorded from the discharge notes. After discharge the children were visited at home within 6 weeks. If they had no current respiratory symptoms and were potty trained, a urine specimen was collected during the visit (convalescent sample).

“Normal” controls were recruited from a random selection of children undergoing elective ear nose and throat surgery or ophthalmic surgery. None had clinical evidence of active infection and their skin prick reactivity to allergens was unknown. Urine for uEPX measurement was obtained before surgery and a blood sample for serum IgE measurement was obtained soon after induction of anaesthesia.

“Atopic normal” controls were recruited from children with suspected food sensitivity who were attending for food challenge. All had history of a suspected allergic reaction to a food and at least one positive skin prick test to food antigens. Serum IgE measurements were not obtained from atopic controls because of ethical restrictions. Controls with a history of chronic respiratory disease, or previous attacks of wheezing, or symptoms of a respiratory tract infection in the preceding week were excluded.

**Follow up**
To establish whether increased uEPX levels during acute PVW were associated with symptoms consistent with a diagnosis of asthma, parents of children who had (1) a 2 year interval from the original admission and (2) reached 5 or more years of age were sent a respiratory questionnaire. Children of school age were categorised either as having “no wheeze” (in the last 6 months) or “current wheeze” (at least one episode of wheeze in the last 6 months).

**Sample collection and analysis**
5–10 ml urine samples were collected using a sterile potty. Urinary infection was excluded using the Multistix 10SG dipstick screening test (Bayer, UK). Urine samples were initially stored in a refrigerator, then aliquoted and transferred to −70°C within 12 hours. The uEPX concentration was measured in unprocessed urine samples using a specific EPX radioimmunoassay kit (Pharmacia, Uppsala, Sweden). Briefly, urine was deproteinised at room temperature and 500 μl used in the assay. The samples were diluted 11 times in a phosphate buffer containing 0.15% NaCl, 1% bovine serum albumin, 0.1% Tween 20, 10 mmol/L EDTA, and 0.2% N-acetyl-trimethylammonium-bromide as previously described. The assay was done in duplicate and the mean values were taken. The detection limit of the assay was <3 μg/l, the within assay coefficient of variation was <5%, and the between assay coefficient of variation was <10%.

**Statistics**
Data are presented as median and interquartile range (IQR). Unpaired data were compared using the Mann-Whitney U test. Paired data were compared using the Wilcoxon signed rank test and expressed as the estimated median difference and 95% confidence interval (CI). Correlations were determined by Spearman rank correlation (rs). Statistical analyses were performed using SPSS for Windows Version 10 (SPSS Inc, Chicago, IL, USA) and Minitab release 13.32 (Minitab Inc, PA, USA). A p value <0.05 was considered statistically significant.

**RESULTS**
Eighty four children with acute PVW were studied. A convalescent urine sample was obtained from 20 children 6 weeks after discharge. Convalescent samples were not obtained from children who were not fully potty trained or refused to produce a sample during the visit (n = 63). One child was excluded because of a readmission with PVW.

**Table 1**
Demographic, serum and urine parameters in children with preschool viral wheeze (PVW) and controls

<table>
<thead>
<tr>
<th></th>
<th>PVW (n = 84)</th>
<th>Normal controls (n = 15)</th>
<th>Atopic controls (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (months)</td>
<td>31 (20 to 41)</td>
<td>59 (41 to 66)**</td>
<td>87 (58 to 101)**</td>
</tr>
<tr>
<td>uEPX (μg/mmol creatinine)</td>
<td>214 (144 to 383)</td>
<td>82 (25 to 211)**</td>
<td>84 (51 to 182)**</td>
</tr>
<tr>
<td>Serum total IgE (kU/l)</td>
<td>56 (9 to 209)</td>
<td>12 (7 to 25)**</td>
<td>Not done</td>
</tr>
<tr>
<td>Absolute eosinophil count (×107/l)</td>
<td>0.1 (0 to 0.2) (n = 73)</td>
<td>0.25 (0.2 to 0.3)*</td>
<td>Not done</td>
</tr>
</tbody>
</table>

Data are presented as median (interquartile range).

*p < 0.05 v PVW, **p < 0.01 v PVW (Mann-Whitney U test). There was no difference in age or urinary eosinophil protein X (uEPX) levels between normal and atopic controls.
FIGURE 1. Dotplot of urinary EPX (uEPX) levels in children with acute PVW (n = 84), normal controls in whom skin prick reactivity was unknown (n = 15), and atopic controls (n = 8). uEPX levels were higher in the children with acute PVW (*p < 0.001 v normal controls; **p < 0.01 v atopic controls, Mann-Whitney U test). Horizontal bars represent medians.

between the acute and convalescent phases of PVW (median −107 μg/mmol creatinine, 95% CI −217 to −31, n = 20, p < 0.05, fig 4). Convalescent uEPX levels were similar to those of normal- and atopic controls (p = NS). When convalescent uEPX levels were categorised by the presence of eczema (7/20), there was no difference between children with and without eczema, and no difference between children with eczema and normal controls.

Follow up questionnaires were returned for 25 (45%) of the 55 children who had reached school age in 2003 and who were at least 2 years post admission. Eighteen children continued to have parent reported wheeze in the preceding 6 months (table 2); all had been prescribed inhaled salbutamol and 11 were receiving regular inhaled steroids. Seven children had no wheeze over the preceding 6 months; none were prescribed inhaled therapy. There was no difference in EPX levels when acute PVW was categorised by the presence or absence of wheeze at the 2 year follow up (table 2).

DISCUSSION
The main finding of this study is that uEPX levels are increased in acute PVW and fall when wheezing resolves. The large degree of overlap between uEPX levels in acute PVW and normal controls suggests a marked heterogeneity of eosinophil activation and is compatible with epidemiological studies suggesting that PVW is not a single phenotype. We originally hypothesised that the highest uEPX levels would occur in children at increased risk of atopic sensitisation. However, no correlation was found between uEPX and serum IgE levels during acute PVW. Other risk factors for eosinophil activation with PVW could not be identified, since no demographic or clinical parameter at the time of admission was associated with increased uEPX levels.

Increased levels of uEPX during PVW did not predict persistence of wheeze into the early school age years. These data would appear to be different from those reported by Øymar who found increased uEPX in wheezy preschool children who were subsequently diagnosed with atopic asthma. We did not perform skin prick tests at follow up, and an association between acute uEPX and a subsequent diagnosis of “atopic” asthma has not been excluded. However, children who continued to wheeze would be considered as “asthmatic” under the current British Thoracic Society guidelines. Thus, increased uEPX levels do not signify a “pre-asthmatic” state in our population of children with PVW. Furthermore, the lack of association between IgE and uEPX levels suggests that eosinophil activation in PVW is not initiated by atopic mechanisms. A primary role for the neutrophil in initiating viral wheeze has recently been hypothesised for preschool children.

Indeed, our previous data showing increased neutrophil activation in a separate group of children with PVW are compatible with a direct role of neutrophils in initiating systemic eosinophil

FIGURE 2. Scatterplot of the association between urinary eosinophil protein X (uEPX) levels and serum IgE levels during acute PVW (r₂ = 0.17, p = NS).

FIGURE 3. Scatterplot of the association between urinary eosinophil protein X (uEPX) levels during acute PVW and time of urine sample from oral prednisolone therapy (r₂ = 0.1, p = NS).

FIGURE 4. Change in urinary eosinophil protein X (uEPX) levels between the acute and convalescent phase of PVW. *p < 0.05, 95% CI −217 to −31 μg/mmol creatinine, n = 20, Wilcoxon signed rank test.
activation, independent of atopic mechanisms. Further studies are needed which combine markers of neutrophil activation with eosinophil markers in order to elucidate the sequence of inflammatory events in PVW.

Could a confounding factor account for the disassociation between serum IgE and uEPX levels? Corticosteroids down-regulate eosinophil activation,19 although there is a time lag of several hours between oral steroid therapy and its systemic effects.19 All children received a single dose of oral prednisolone on admission, which may therefore have disrupted an association between IgE and uEPX. However, uEPX levels in samples taken within the first hours of admission were no different from those obtained later (fig 3), a pattern that does not indicate therapeutic suppression. Eczema is another potential confounder, since active dermatitis is associated with increased uEPX levels17 and a significant minority (32%) of children with PVW had mild eczema. However, eczema was not associated with increased uEPX levels, either during the acute or the convalescent phase of PVW.

The normalisation of uEPX on convalescence implies that eosinophil activation in children with PVW is an acute, but not a chronic, phenomenon. Indeed, eosinophil activation was not found in a bronchoalveolar lavage study of children with a history of episodic viral trigger wheeze.20 The fall in uEPX levels on convalescence from PVW suggests a role for eosinophils in the pathogenesis of wheeze. However, we have not excluded systemic eosinophil activation with colds per se, although this is unlikely since uEPX levels are not increased in young children with trivial upper respiratory tract illnesses.19

In conclusion, we found evidence of eosinophil activation in children with severe acute PVW which normalised with resolution of symptoms. Eosinophil activation in PVW is independent of serum IgE, clinical presentation, and outcome 2 years later. We speculate that eosinophil activation in PVW is not caused by an atopic inflammation but is a result of direct stimulation by non-atopic inflammatory cells.

Table 2 Two year follow up of children with preschool viral wheeze (PVW) who had reached 5 years of age in 2003

<table>
<thead>
<tr>
<th>Age at PVW episode (months)</th>
<th>37 (31 to 43)</th>
<th>34 (25 to 46)</th>
</tr>
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<tbody>
<tr>
<td>Age at follow up (months)</td>
<td>77 (74 to 86)</td>
<td>83 (73 to 95)</td>
</tr>
<tr>
<td>IgE during PVW episode (kU/l)</td>
<td>141 (57 to 235)</td>
<td>31 (10 to 294)</td>
</tr>
<tr>
<td>uEPX during PVW episode (µg/mmol creatinine)</td>
<td>245 (166 to 387)</td>
<td>310 (203 to 451)</td>
</tr>
</tbody>
</table>

Data are presented as median (IQR). There were no differences between the two outcome groups (p = NS, Mann–Whitney U test).

*Parental reported symptoms over the previous 6 months.

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