Acidosis, non-invasive ventilation and mortality in hospitalised COPD exacerbations

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ABSTRACT

**Background** Reports of non-invasive ventilation (NIV) use in clinical practice reveal higher mortality rates than in corresponding randomised clinical trials.

**Aim** To explore factors related to chronic obstructive pulmonary disease (COPD) admissions and NIV use that may explain some of the previously reported high mortality rates.

**Methods** National UK audit of clinical care of consecutive COPD admissions from March to May 2008. Retrospective case note audit with prospective case ascertainment. Participating units completed a web-based audit proforma of process and outcomes of clinical care.

**Results** 232 hospital units collected data on 9716 patients, mean age 73, 50% male. 1678 (20%) of those with gases recorded on admission were acidotic and another 6% became acidotic later. 1077 patients received NIV, 55% had a pH<7.26 and 49% (305/618) had or were still receiving high flow oxygen. 30% (136/453) patients with persisting respiratory acidosis did not receive NIV while 11% (15/131) of acidotic admissions had a pure metabolic acidosis and did. Hospital mortality was 25% (270/1077) for patients receiving NIV but 39% (86/219) for those with late onset acidosis and was higher in all acidotic groups receiving NIV than those treated without. Only 4% of patients receiving NIV who died had invasive mechanical ventilation.

**Conclusions** COPD admissions treated with NIV in usual clinical practice were severely ill, many with mixed metabolic acidosis. Some eligible patients failed to receive NIV, others received it inappropriately. NIV appears to be often used as a ceiling of treatment including patient groups in whom efficacy of NIV is uncertain. The audit raises concerns that challenge the respiratory community to lead appropriate clinical improvements across the acute sector.

**BACKGROUND**

Non-invasive ventilation (NIV) is an evidence-based treatment recommended for acute respiratory acidosis for defined patients admitted with exacerbations of chronic obstructive pulmonary disease (COPD). A synthesis of the relevant randomised controlled trials (RCTs) has been used to produce national guidelines outlining the indications and practical issues around its use by acute hospital units. The 2003 UK national COPD audit included data collection on the use of NIV in usual clinical practice and described survival rates significantly below those reported in RCTs used as a basis for the national recommendations. Questions were raised about the appropriate application of NIV outside controlled trial conditions. While the 2005 audit data were unable to provide adequate explanations for the high mortality, the authors of the paper suggested ‘confounding factors’, unidentified factors and poor patient selection as probable reasons for the observed outcomes.

In 2008, the Royal College of Physicians (RCP), British Thoracic Society and the British Lung Foundation undertook a further round of national audit of the acute care of COPD patients admitted to hospital and included additional data items to further explore issues raised by the 2003 audit. This paper reports the findings of the 2008 national audit with reference to the use of NIV in COPD patients admitted with an exacerbation.

**METHODS**

The 2008 audit collected data in five different areas of COPD care and details can be viewed at http://www.rcplondon.ac.uk/clinical-standards/ceeu/Current-work/ncrop/Pages/audit.aspx. All UK and island Trusts admitting COPD exacerbation patients were invited to participate in the audit programme and to collect data as acute units. The term ‘unit’ was used to describe each participating organisation and was defined as ‘a hospital that admits acute unselected emergency admissions’. Thus, where a whole Trust participated in the audit, the term ‘unit’ refers to that Trust. Where a hospital participated as part of a Trust, the term ‘unit’ refers only to that hospital within the Trust. Participants were asked to define ‘units’ in terms of the functionality of their Respiratory Medicine Departments.

Units completed a retrospective case note audit of up to 60 consecutive patients with admissions identified prospectively between March and May 2008. An admission for COPD was defined as a senior physician made diagnosis on the post take ward round. The lead audit physician in each unit was encouraged to validate diagnoses at discharge and exclude cases where the diagnosis had subsequently been changed and to exclude cases where an admission diagnosis was not COPD but had subsequently been changed to COPD. Cases with radiological changes were included in the audit if the senior admitting physician defined the admission as exacerbation of COPD as the primary diagnosis. The audit collected items relating to process of care and clinical outcomes within 90 days of the index admission. Data were entered onto a bespoke web-based programme and collated centrally at the RCP. Patients were divided into...
subgroups for purposes of analysis according to arterial blood gas pH measurements and whether they received NIV.

The reliability of the clinical case data was assessed by asking units to double enter data on the first five cases using a different auditor. The levels of reliability for 952 submitted cases were generally good with κ values of 0.60 and higher dominating with many over 0.80 (very good), but the reporting of the administration of high flow oxygen before admission was less good (κ 0.48) with κ values of between 0.40 and 0.59 regarded as representing ‘fair’ agreement. Data were analysed using SPSS (SPSS Inc. V15). Missing data values affect patient denominators accordingly. Binary-level data were compared between patient subgroups using either Fisher’s exact test (2 subgroups) or the χ² test (>2 subgroups); numerical data were compared using either the Mann–Whitney test (2 subgroups) or the Kruskal–Wallis test (>2 subgroups). We used random effects logistic regression (STAT8, Stata corporation) to adjust for site clustering to give NIV treatment ORs for mortality adjusted for independent predictors. Variables adjusted in the logistic regression comprised of age (<65, 65–74, 75–94, 95+), performance score (5 levels), lowest acidicotic pH (quintiles), initial pH (<7.26, 7.26–7.34, 7.34+), blood urea (≥7.1, >7.1), serum albumin (<34, 34+), CCR cancer (Yes/No), weight (tertiles), peripheral oedema (Yes/No), PaCO2(≤6.0, 6.0+), PO2 (<7.3, 7.3–8.0, >8.0), BIC (23, 23–50, >50), Creatinine (tertiles) and acidicotic prognostic group (groups 1, 2 and 3 as defined in this paper). Missing values for covariates were coded to preserve the full sample size in the regression. Reliability of the parameter estimates were checked and confirmed using the quadchk command within Stata.

Ethics approval was given by the University College Hospital/ University College London MREC.

RESULTS

Patient characteristics

Clinical data for 9716 patients were received from 232 units within 177 of 184 (96%) of all eligible acute Trusts. The median number of cases contributed by units was 46, inter-quartile range (IQR) 29–58. Overall mean (SD) patient age was 73 (10) years and half (4906) were male. The mean (SD) FEV1% predicted was 42% (18%) for the 5199/9716 for whom it was recorded. Where indicated 98% (8681/8863) of patients were predicted was 42% (18%) for the 5199/9716 for whom it was predicted. Where indicated 98% (8681/8863) of patients were predicted was 42% (18%) for the 5199/9716 for whom it was predicted. Where indicated 98% (8681/8863) of patients were predicted was 42% (18%) for the 5199/9716 for whom it was predicted.

Arterial blood gases (ABG)

NICE COPD guidelines recommend an arterial blood gas be taken on admission (NICE 2004). Whether or not ABG were taken at admission was recorded in 99% (9596) of cases and 87% (8340) had gases taken. Twenty per cent (1678/8215) were acidotic on admission. Acidotic patients had higher levels (all at p<0.001) of residential placement (8% vs 4.5%), of receiving some form of care (45% vs 38%), a poor performance status (11% vs 6% chair or bed bound) and a pre-admission MRC dyspnoea score of 5 (41% vs 29%) compared with non-acidotic patients. Mean (SD) FEV1% predicted when known for 866/1678 acidotic cases was 34% (17%), as compared with 42% (19%) for 3628/6557 non-acidotic cases, p<0.001. Asian/British Asian patients presented with a higher level of acidosis (31% 28/91) in the audit than other patients with known ethnicity (20%, 1516/7407), p=0.02. Of the 1678 who were acidotic on admission 45% (750) received NIV and of these 76% (559/756) were recorded as having one or more co-morbidities with 18% (132/736) having three or more co-morbidities, similar to the 77% (7459/9716) and 19% (1865/9716), respectively, for all patients.

NICE guidelines recommend that the aim of oxygen therapy is to maintain adequate levels of oxygenation without precipitating respiratory acidosis or worsening hypercapnia (NICE 2004). Fifty per cent of patients (4864/9716) were receiving oxygen at the time of the initial blood gas and 30% of these (1385/4685) received more than 28% or 4 l by nasal cannulae at that time. Thirty per cent (1491/5052) recorded had received >35% oxygen in the ambulance prior to admission and 35% (491/1388) were still receiving this when admission gases were taken. There was a strong relationship between the timing since high flow oxygen was received and the degree and prevalence of acidosis in the admission arterial blood gas (table 1). High flow oxygen was received by 49% (305/618) who received NIV, and by 57% (245/425) of patients who received NIV and who were acidicotic on admission, p=0.01. High flow oxygen was associated with subsequent ventilatory support (22%, 351/1491 vs 9%, 536/5361, p<0.001) and with higher in-hospital mortality (11.1% 165/1491 vs 7.2%, 256/3561, p<0.001). Patients who were acidicotic on admission having received high flow oxygen, however, had similar in-hospital mortality as patients who were acidicotic on admission and did not receive high flow oxygen (16.9%, 88/522 vs 14.9%, 60/405, p=0.47).

The arterial gas measurements recorded by the audit are summarised in table 2 in which 2143 patients with a recorded acidosis are also stratified into three groups. In the first group, 1225/2143 (57%) had their lowest pH on their initial admission ABG. In the second group of patients who also presented with acidosis, 455/2143 (21%), went on to have a lower pH recorded further into the admission. For this group, the median (IQR) time interval between initial blood gas and lowest blood gas pH was 5 h (2–24 h). The third group of patients 465/2143 (22%) had a normal range pH on admission, but became acidic later in the admission. In this group, the median (IQR) time from admission to the lowest recorded pH was 24 h (7–72 h). These patients were no more likely to have co-morbidities recorded (79% vs 77%) and specifically no more likely to have diabetes (13% vs 11%) or cardiac disease (ischaemic heart disease 22% vs 26%; cardiac arrhythmia 9% vs 10%; other cardiovascular disease 18% vs 20%) recorded than patients admitted with a normal pH and who did not become acidic later.

| Table 1 Relationship between the interval since high flow oxygen was received and prevalence of acidosis and hypoxia in the admission arterial blood gas |
|---|---|---|
| % with pH<7.35 on admission | % with PaO2≤8.0 on admission |
| (%) | (%) |
| Proportion of cases with: |
| High flow oxygen not received before arterial gases taken | 14 (403/2942) | 38 (1143/2983) |
| Time interval between high flow oxygen stopped and blood gases taken: |
| >60 min before gases | 20 (107/537) | 39 (211/538) |
| >15 but ≤60 min before gases | 36 (127/350) | 34 (120/352) |
| ≤15 min before gases | 52 (44/85) | 33 (28/85) |
| χ² p value (comparing above three groups) | p<0.001 | p=0.22 |
| Still receiving high flow oxygen when gases taken | 52 (244/471) | 11 (53/479) |

Table 2  Arterial blood gas results as recorded in the national audit for the three acidotic patient subgroups

<table>
<thead>
<tr>
<th>pH</th>
<th>All cases on admission N=8215</th>
<th>ACIDOTIC on admission, this being the lowest pH (group 1) N=1225</th>
<th>ACIDOTIC on admission, later lowest pH ALSO ACIDOTIC (group 2) N=453</th>
<th>ACIDOTIC on admission, later lowest pH NOT ACIDOTIC (group 3) N=465</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;7.26</td>
<td>7% (557)</td>
<td>35% (427)</td>
<td>29% (130) 60% (272)</td>
<td>– 0 32% (151)</td>
</tr>
<tr>
<td>7.26–7.34</td>
<td>14% (1121)</td>
<td>65% (798)</td>
<td>71% (323) 40% (181)</td>
<td>– 0 68% (314)</td>
</tr>
<tr>
<td>7.35+</td>
<td>80% (6537)</td>
<td>— 0</td>
<td>— 0</td>
<td>100% 465 — 0</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>7.41 (7.36–7.45)</td>
<td>7.29 (7.22–7.32)</td>
<td>7.30 (7.26–7.32) 7.24 (7.18–7.27)</td>
<td>7.39 (7.36–7.41) 7.29 (7.23–7.32)</td>
</tr>
<tr>
<td>Bic</td>
<td>&lt;23</td>
<td>14% (1096)</td>
<td>16% (187)</td>
<td>14% 61 17% 73</td>
</tr>
<tr>
<td>23–30</td>
<td>65% (5104)</td>
<td>51% (584)</td>
<td>44% 191 39% 168</td>
<td>57% 256 48% 204</td>
</tr>
<tr>
<td>&gt;30</td>
<td>21% (1628)</td>
<td>33% (373)</td>
<td>42% 186 44% 191</td>
<td>33% 148 31% 140</td>
</tr>
<tr>
<td>PCO₂</td>
<td>&lt;8.0</td>
<td>34% (3601)</td>
<td>91% (1090)</td>
<td>95% 429 96% 436</td>
</tr>
<tr>
<td>&gt;8.0</td>
<td>56% (4628)</td>
<td>9% (107)</td>
<td>5% 24 4% 16</td>
<td>39% 182 11% 49</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>8.4 (7.9–8.2)</td>
<td>8.8 (7.3–10.9)</td>
<td>9.0 (7.6–10.5) 10.3 (8.7–12.4)</td>
<td>6.5 (5.4–7.6) 8.7 (7.3–10.1)</td>
</tr>
<tr>
<td>PO₂</td>
<td>&lt;7.3</td>
<td>21% (1691)</td>
<td>19% (230)</td>
<td>35% 158 24% 109</td>
</tr>
<tr>
<td>7.3–8.0</td>
<td>14% (1125)</td>
<td>7% (87)</td>
<td>9% 41 9% 39</td>
<td>13% 60 10% 47</td>
</tr>
<tr>
<td>&gt;8.0</td>
<td>66% (5415)</td>
<td>74% (883)</td>
<td>56% 254 67% 302</td>
<td>49% 226 65% 303</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>8.9 (7.6–11.3)</td>
<td>10.4 (7.9–14.8)</td>
<td>8.6 (6.5–11.9) 9.3 (7.5–12.5)</td>
<td>8.0 (6.6–9.7) 9.1 (7.3–11.5)</td>
</tr>
</tbody>
</table>

NICE guidance recommends that ABG be repeated regularly according to the response to treatment (NICE 2004). A repeat blood gas was taken for 1635/2143 acidotic patients and the time interval to the repeat gas was categorised as <1 h (26%, 450), >=1 but <2 h (28%, 454), 2–4 h (21%, 349) and >4 h (25%, 402).

Non-invasive ventilation

Guidelines recommend that NIV be commenced within 1 h of admission in all patients in whom a respiratory acidosis persists despite maximum medical therapy (RCGP 2008). Twelve per cent (1162/9716) of all patients received ventilatory support of whom 1032 (88%) received NIV alone, 45 (4%) NIV with invasive and/or doxapram, 88 (8%) invasive alone and 3 (0.3%) doxapram alone. While 70% (317/453) of patients with both admission and subsequent lower acidotic ABGs received NIV, this means that nearly one third of those with the greatest evidence base for effectiveness did not. Only 35% (453/1225) of those with an initial acidosis but subsequent better pH did so, as did 47% (219/465) of those admitted with a normal pH but who later developed acidosis, p<0.001. The time interval from admission to receiving NIV is summarised in table 3. Eight per cent (131/1650) of acidotic patients on admission with a known PaCO₂ had a normal PaCO₂ implying a metabolic cause for the deranged pH. Of these, 11% (15/131) received NIV. For 76 patients becoming acidotic after admission (group 3) with a PaCO₂ ≤ 6.0 kPa on admission 7% (5) received NIV within an hour, 9% (7) within 1–3 h, 32% (24) within 3–24 h and 53% (40) after 24 h. This was similar to the 142 group 3 patients with PaCO₂ > 6.0 kPa on admission with 5% (7) receiving NIV within an hour, 9% (13) within 1–3 h, 42% (60) within 3–24 h and 44% (62) after 24 h. All but group 1 and group 2 patients who were acidotic on admission and who received NIV had PaCO₂ values of 6.0 and above on admission.

Of patients with pH<7.26 on admission 66% (370/557) received NIV, compared to 34% (380/1121) with pH 7.26–7.34 and 5% (297/6577) if non-acidotic. Of patients with lowest pH<7.26 at any time 68% (577/850) received NIV, compared with 30% (392/1295) with lowest pH 7.26–7.34 and 1% (78/6078) with non-acidotic lowest pH. Of all 1077 NIV patients, 1047 had gases recorded and 55% (577) had a lowest pH of <7.26 (median 7.19 IQR 7.13–7.22), 37% (392) a lowest pH of 7.26–7.34 and 7% (78) were non-acidotic.

Mortality

In-patient mortality for those receiving NIV was 25% (270/1077) overall, but was 39% for those with late onset acidosis and receiving NIV (table 4). Overall, both patients treated with or not receiving NIV had higher in-patient mortality when admission respiratory rate was 20 or above. For those on admission with a respiratory rate <20, 24% (25/104) and 4% (65/1541), respiratory rate 20–29, 23% (128/549) and 5% (266/5144), respiratory rate 30+, 29% (108/369) and 7% (98/1333). Patients treated with NIV with a low bicarbonate (<23 mmol/l) at time of lowest recorded acidotic pH had a higher mortality than those with a normal or high bicarbonate (>30 mmol/l). In hospital—38% (52/136) versus 22% (83/379) versus 25% (101/398), p=0.001; within 90 days—41% (56/135) versus 29% (103/356) versus 34% (131/386), p=0.03. This overall in-hospital mortality was 12% (152/1225) in those admitted with acidosis being the lowest pH, 24% (109/453) in those admitted with acidosis that subsequently was worse and 33% (153/465) in those with normal pH at admission but later onset acidosis. Of these patients with low bicarbonate only 1 with a pH<7.26 had a PaCO₂<6 kPa suggesting that the vast majority of these patients would have benefited from NIV.

Table 3 Time interval from admission to receiving NIV for patients

<table>
<thead>
<tr>
<th>ACIDOTIC on admission, this being the lowest pH (group 1)</th>
<th>ACIDOTIC on admission, later lowest pH ALSO ACIDOTIC (group 2)</th>
<th>NON-ACIDOTIC on admission, later lowest pH ACIDOTIC (group 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>N=433</td>
<td>N=317</td>
</tr>
<tr>
<td>&lt;0.3 min</td>
<td>17 75</td>
<td>7 23</td>
</tr>
<tr>
<td>0.3–60 min</td>
<td>20 86</td>
<td>14 44</td>
</tr>
<tr>
<td>1–3 h</td>
<td>32 140</td>
<td>31 98</td>
</tr>
<tr>
<td>3–24 h</td>
<td>25 109</td>
<td>38 119</td>
</tr>
<tr>
<td>Beyond 24 h</td>
<td>5 23</td>
<td>10 33</td>
</tr>
</tbody>
</table>


45
cases were a mixed metabolic and respiratory acidosis. Patients with low bicarbonate had higher creatinine values (median 100 μmol/l, IQR 82–143, n=125) than other acidotic patients with a normal bicarbonate (median 85 μmol/l, IQR 66–112, n=558) or high bicarbonate (median 75 μmol/l, IQR 60–98, n=868), p<0.001.

In-patient mortality for patients with pH <7.26 on admission was 26% (95/370) for patients receiving NIV and 20% (58/287) if not receiving NIV, p=0.12; corresponding mortality for patients with pH 7.26–7.34 was 17% (66/380) with NIV and 8% (60/745), p<0.001. For patients in this pH range on admission with a persisting acidosis, 54% (110/323) did not receive NIV and of these 110 18% (20/110) died as an inpatient. For patients in this pH range on admission with a persisting acidosis who did receive NIV 21% (44/213) died as an inpatient. Of patients with acidosis at any time during admission in-patient mortality was 26% (249/969) with NIV and 14% (165/1174) without NIV, p<0.001, while 90-day mortality was 35% (310/932) and 22% (246/1143), respectively, p<0.001.

One thousand five hundred and thirty (16%) admissions had radiological changes described as consistent with pneumonia as did 225 (21%) of those who had received NIV. For each acidotic prognostic group mortality rates were higher for those with pneumonia, but there were no statistically significant differences. For all patients receiving NIV, in-patient mortality was 30% (67/223) with pneumonia and 24% (203/854) without pneumonia (p=0.06).

In the analysis of data from the 2003 national audit,5 the main predictors of inpatient and 90-day mortality were age, performance score, lowest pH, initial PaO2, blood urea and serum albumin, oxygen saturation, CXR cancer, weight and peripheral oedema. Apart from oxygen saturation all these covariates were predictors of inpatient and 90-day mortality were age, perfor-
nance score, lowest pH, initial pH, blood urea and serum albumin, oxygen saturation, CXR cancer, weight and peripheral oedema. Apart from oxygen saturation all these covariates were predictors of inpatient and 90-day mortality were age, perfor-

### Inpatient mortality

<table>
<thead>
<tr>
<th>pH Acidity Status</th>
<th>For ALL Patients not receiving NIV</th>
<th>For ALL Patients receiving NIV</th>
<th>Fishers Exact test (NIV versus not NIV)</th>
<th>90-day mortality*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acidotic patients</strong></td>
<td>14 165/1174 26 249/969</td>
<td>11 949/8269 33 310/932</td>
<td>&lt;0.001</td>
<td>10 145/1399 58 152/26</td>
</tr>
<tr>
<td><strong>Non-acidotic patients</strong></td>
<td>4 246/5994 10 878</td>
<td>2 246/1143 33 310/932</td>
<td>&lt;0.001</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>No admission gases</strong></td>
<td>4 64/1471 43 13/30</td>
<td>4 64/1471 43 13/30</td>
<td>&lt;0.001</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>ACIDOTIC on admission, this being the lowest pH (group 1)</strong></td>
<td>9 70/792 19 82/433</td>
<td>9 70/792 19 82/433</td>
<td>&lt;0.001</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>ACIDOTIC on admission, later lowest pH (group 2)</strong></td>
<td>21 28/136 26 81/317</td>
<td>21 28/136 26 81/317</td>
<td>&lt;0.001</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>NON-ACIDOTIC on admission, later lowest pH (group 3)</strong></td>
<td>27 67/246 39 86/219</td>
<td>27 67/246 39 86/219</td>
<td>&lt;0.001</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*p value (comparing above 3 groups) p<0.001 p<0.001 p<0.001 p=0.003

*Within 90 days from index admission.

### DISCUSSION

This study of the clinical care of 9716 patients admitted with COPD contains the largest group of prospectively identified patients treated with NIV in the literature. We report findings similar to those of the 7529 patients described in the 2003 National Audit.5 In essence, patients treated in usual clinical practice with NIV appear to have much poorer outcomes than those reported in the RCTs on which the recommendations for what to do in the event of failure was documented, but for 12% (52/270) of those dying in hospital no plan was recorded. For 40% (451/1077) treated with NIV a Do Not Resuscitate order was signed, but for 30% (62/270) of NIV patients who died no order was evident. Fifty per cent (1079/2145) of patients with a recorded acidosis did not receive any form of ventilatory support. The reasons documented for not providing ventilatory support were: patient responded to medical therapy (60%, 648), medical decision not to escalate (14%, 149), patient refused NIV (4%, 38), no facilities available (5%, 50), failed (n=4). No apparent reason to withhold NIV or invasive ventilation could be discerned by auditors in 19% (210) of cases.

The 2008 NIV guidelines recommend that a decision not to escalate to invasive ventilatory support should be taken by a consultant (RCP 2008). For 11% (16) of the 149 cases where a medical decision was made not to escalate to NIV this decision was documented as being made by a Senior House Officer equivalent or more junior (Foundation Year 1\[FY1\]/Foundation Year 2\[FY2\]/Speciality Trainee year 1 or 2 \[ST1/2\] now Core Trainee year 1 \[CT1/2\]). In 50% (75/149), the decision was taken by a Specialist Registrar or ST 3–5. The following reasons were given for not escalating to NIV: poor pre-morbid functional status, multiple co-morbidities, malignant disease, patient’s wishes, previously failed trial of NIV, metabolic acidosis.

### Invasive mechanical ventilation (IMV)

NICE guidance states that patients with exacerbations of COPD should receive treatment on intensive care units, including invasive ventilation, when this is thought to be necessary (NICE 2004). Only 1% (122/9716) of patients in 91 of 252 units received IMV. Five per cent (110/2143) of all acidotic patients received it, as did 5% (38/745) of all inpatient deaths and 3% (44/1289) of all those who died within 90 days. Some 3.2% (34/1031) of NIV patients who died within 90 days.

### Documentation of ventilatory plan

National guidelines recommend that a plan of action in the event of failure to respond to NIV be documented in the case notes (RCP 2008). For 60% (643/1077) of NIV patients a plan of
the use of NIV are based. The fact that the observed mortality in patients treated with NIV is higher than patients matched by arterial blood gas pH who do not receive NIV and is similar to that of the control group in the YONIV trial. The data reported offer a number of explanations for these findings that in summary suggest that the patients treated in usual clinical practice are different from those included in the RCTs with many having severe acidosis with NIV used as the ceiling of care. It is also seen that some with metabolic acidosis receive NIV inappropriately while a proportion of patients who meet the RCT inclusion criteria of persisting respiratory acidosis do not receive NIV.

We have identified three groups of COPD patients defined by the timing of acidosis who have very different prognoses when managed by NIV. Those admitted with acidosis whose repeat gas improve have the best outcome followed by those who have two sets of acidic gases. For these groups, the audit raises significant concerns about the standard of medical management. The first is the use of relatively high flow rates of oxygen prior to and after admission where there is not only a significant relationship with the degree of admission acidosis (table 1) but also adverse outcomes of need for ventilatory support and death. The second is the potential impact of delay in initiation of NIV after admission. National guidelines recommend the application of NIV if after 1 h of usual medical management ABG, patients fail to respond. In those whose worse ABG was on admission less than a half of these patients received NIV within the first hour and 50% after at least 3 h had passed (table 3). While there may be concerns that NIV could be administered too quickly and unnecessarily in cases of oxygen poisoning the evidence here suggests delayed initiation. For those whose acidotic arterial pH deteriorated following admission less than a quarter received NIV in the first hour and 48% following at least a 3 h interval (table 3).

The third group identified comprises those patients admitted without acidosis but who then develop this later in the admission. Their outcome is particularly poor with mortality rates approaching five times that reported in the RCTs and clinicians may be falsely reassured by a normal admission pH. It is likely from the blood gas analysis that some of these patients have a mixed metabolic/respiratory acidosis while a pure metabolic acidosis seems to be the exception. There is little in the NIV literature relevant to this group although Moretti describes a group of late acidosis patients with a particularly poor prognosis if managed using NIV rather than IMV but these patients were admitted with acidosis and later relapsed after initial improvement on NIV. Patients with a low arterial blood bicarbonate level have worse outcomes. These patients are more likely to have renal impairment too but for most this is mild. It is important that physicians managing these patients do not over-rely on NIV to correct an acidosis that has an underlying metabolic component and arguably such patients when identified may be better managed on an HDU/ICU facility.

It appears that in clinical practice a range of severely acidotic patients are treated with NIV as the sole means of ventilatory support. In RCTs that have examined this approach as first line management intubation rates in severe acidotic COPD are over 50% and if accompanied by pneumonia as high as 100%. Although subject numbers in prospective studies are small, the results of this clinical audit are consistent with the trials. It is clear that most patients receiving NIV have severe acidosis and a high mortality and for whom published guidelines suggest IMV should be considered sooner rather than later. In the audit, only 1% of admissions and only 5% of all acidotic patients in only 91 of 252 secondary care centres received IMV. Only 3% of those with NIV and 3% of those managed initially with NIV but who subsequently died received IMV. We neither know how many of the NIV patients were managed in HDU and ICU beds than access to IMV was optimal nor know the exact circumstances for the low rate of ventilatory support recorded. We can note the low IMV rates observed here compared against the higher ventilation rates recorded in the USA the reported inconsistency in decision making within the UK that may deny patients life saving treatment. COPD patient studies demonstrating preferences for ITU and IMV. What is known is that in 12% of cases managed with NIV who subsequently died there was no plan in the case notes of what the ceiling of treatment was in the event of failure of NIV. In 50% of cases who died following NIV a ‘Do Not Resuscitate’ order was not signed. Of those acidotic patients not given even NIV this decision was taken by a very junior trainee in 11% of cases and in a further 50% by a registrar grade doctor.

In contrast, the group of patients for whom there exists the strongest evidence base for the effectiveness of NIV, those with a pH range of 7.26–7.35, form only a minority of those overall receiving NIV. While case by case reasons for this are not known in detail, it was stated in 60% of acidotic patients who did not receive NIV that they had responded to medical therapy and the data concerning receipt of high flow oxygen therapy prior to admission give the cause for concern here. Some of these patients will improve simply by reducing oxygen flow while others may receive NIV inappropriately and this is to an extent justified by the better overall survival figures for this group (17% if treated with NIV and 8% if managed without if admission pH 7.26–7.35). However, 54% of patients with an admission pH in the 7.26–7.35 range but with a persisting acidosis where the indication for NIV is strongest did not receive NIV and 18% of these patients died. In addition, in 3% of acidotic admissions there were no NIV facilities available and in 19% of cases the auditors were unable to discern a documented reason for not offering NIV.

This report is limited in the conclusion that can be drawn as the details of decision making over individual cases are not available beyond the descriptions given above. This was not a prospective RCT but a survey of current clinical practice. In some instances data are missing specifically the FEV₁ in 46% cases to confirm the diagnosis of COPD. Audit reporting may contain inaccuracies particularly in the giving and timing of high flow oxygen pre-admission. This is, however, a comprehensive snapshot of care in nearly every UK secondary care unit and is based upon nearly 10,000 clinical cases of whom over a 1000 received NIV during the data of any existing prospective clinical trial. The data from this audit are entirely consistent with those collected from 7529 admissions in 2003 of whom 26% had acidosis recorded at some time in the admission and of whom 31.4% (529) received NIV with a 26% in-hospital mortality.

This study has provided data that explain some of the high mortality observed among acidotic patients admitted to hospital and treated with NIV. It also raises concerns about the use of high flow oxygen, the timing of ABG and initiation of NIV and the management of acidosis in the presence of metabolic disturbance. Equally the report highlights a proportion of eligible patients with arterial pH range demonstrated in randomised trials to benefit from NIV who do not go on to receive NIV in usual clinical practice. NIV appears to be used as the ceiling of treatment in very sick patients with an often poorly defined escalation pathway determined by junior medical staff. Acute physicians, general physicians and geriatricians on call, emergency staff, anaesthetists and intensivists all initiate and manage...
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COPD patients using or not using NIV. The challenge to the respiratory community is to respond to the audit findings by defining optimum care for the whole range of acidoic patients seen in clinical practice and to implement national standards fully leading by example.

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REFERENCES

Acidosis, non-invasive ventilation and mortality in hospitalised COPD exacerbations

C M Roberts, R A Stone, R J Buckingham, N A Pursey and D Lowe

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