A placebo-controlled study of three osteocalcin assays for assessment of prednisolone-induced suppression of bone turnover

C Heuck and O D Wolthers
Department of Paediatrics, Aarhus University Hospital, Aarhus, Denmark
(Requests for offprints should be addressed to O D Wolthers, Department of Paediatrics, Randers Hospital, DK-8900 Randers, Denmark)

Abstract
Serum osteocalcin is a sensitive marker of suppressive effects of exogenous glucocorticoids on bone turnover. It has been suggested, however, that the degree of suppression detected by different assays may vary. Whether discrepancies between various assays influence conclusions from group studies of exogenous glucocorticoids has not been evaluated. The aim of the present study was to compare the CAP fluoroimmunoassay (FEIA), OSTK-PR and ELSA-OSTEO assays for assessment of prednisolone-induced effects on serum osteocalcin. Twelve men and eight premenopausal women aged 19–45 (mean 31) years were studied. All subjects were healthy. The design was a randomised double-blind, placebo-controlled parallel-group study with 2 days run-in, 3 days treatment and 4 days run-out. During run-in and run-out no medication was given. During the treatment period the subjects took either 20 mg prednisolone twice daily or placebo. Blood was collected on the last day of each period. Intra- and intergroup comparisons showed prednisolone treatment to be associated with a statistically significant suppression of osteocalcin which was detected by all assays (ANOVA; P<0.0001). In the individual subjects the response to prednisolone was the same for each assay. The CAP FEIA, OSTK-PR and ELSA-OSTEO assays seem equally sensitive for evaluation of osteocalcin in group studies of oral glucocorticoids.

Introduction
Osteocalcin is the most abundant noncollagenous protein of bone. It is synthesised only by the osteoblasts, and changes in osteoblast activity correlate with variations in serum concentrations of osteocalcin (Nielsen et al. 1988b). Serum osteocalcin has been established as a sensitive marker of suppressive effects of exogenous glucocorticoids on bone turnover (Nielsen et al. 1988a,b, Meeran et al. 1995). Systemic glucocorticoids cause a dose-dependent reduction in osteocalcin levels (Hodsman et al. 1991, Wolthers et al. 1993). It has been suggested, however, that the degree of glucocorticoid suppression detected by various assays may vary, whereby interpretation of osteocalcin in individual patients treated with exogenous glucocorticoids becomes difficult (Masters et al. 1994). Whether discrepant test results may influence conclusions from group studies of exogenous glucocorticoids has not been evaluated. Therefore, the aim of the present study was to assess whether prednisolone treatment is associated with any adverse effects on serum osteocalcin using three osteocalcin assays.

Subjects and Methods
Twelve men and eight women aged 19–45 (mean 31) years, doctors and nurses, laboratory workers and students at our department, were asked and agreed to participate in the study. The subjects were carefully screened by medical examination and proved healthy without any history of metabolic or renal disease. None of them had ever received treatment with exogenous glucocorticoids and no other drugs were taken 2 months before or during the study period. All subjects were non-smokers. None of the females was pregnant or had menstruation during the study. All subjects entered the study on the same day, and they continued their usual activities throughout the study. The study was approved by the local ethics committee, and each subject gave informed consent before the study.

The design was a randomised double-blind, placebo-controlled parallel-group study with 2 days run-in, 3 days treatment and 4 days run-out. During run-in and run-out no medication was given. During the treatment period the subjects took either 20 mg prednisolone twice daily or placebo. Blood was collected on the last day of each period. Intra- and intergroup comparisons showed prednisolone treatment to be associated with a statistically significant suppression of osteocalcin which was detected by all assays (ANOVA; P<0.0001). In the individual subjects the response to prednisolone was the same for each assay. The CAP FEIA, OSTK-PR and ELSA-OSTEO assays seem equally sensitive for evaluation of osteocalcin in group studies of oral glucocorticoids.
Glass tubes without clot accelerators were used for the collection of blood which took place during the afternoon between 1300 and 1700 h on the last day of the run-in, treatment and run-out periods. The blood samples were taken at roughly the same time (that is, within 30 min) and were centrifuged at 4000 r.p.m. for 10 min within 1 h of collection. After centrifugation serum samples were stored in plastic tubes at \(-80^\circ\text{C}\), and they were thawed only once, i.e. immediately before they were batch assayed at completion of the study, each sample being run in all three assays at the same time. Haemolysed samples were not used for analysis. The osteocalcin assays used were Pharmacia Osteocalcin CAP fluorimunoassay (FEIA) (Kabi Pharmacia Diagnostics AB 1994) and CIS Human Osteocalcin IRMA (ELSA-OSTEO) (Cis Bio International 1994) and RIA (OSTK-PR) (CIS Bio International 1995). Details of the assays are given in Table 1. In the CAP FEIA osteocalcin standards were calibrated against a reference standard, which was prepared according to a modified method (Taylor et al. 1988) and quantified by amino acid analysis. In the ELSA-OSTEO and OSTK-PR assays animal proteins (ELSA-OSTEO) and bovine osteocalcin and human proteins (OSTK-PR) were used in lyophilised standards. Normal ranges of serum osteocalcin depend on sex, age and the assay used (Gundberg et al. 1985, Tarallo et al. 1990). Preliminary assessments using the CAP FEIA, OSTK-PR and ELSA-OSTEO assays have found normal ranges of 1–25, 1–18 and 5–35 µg/l respectively, in 20- to 50-year-old men, and of 1–15, 1–13 and 8–36 µg/l respectively, in 20- to 50-year-old, premenopausal women (Kabi Pharmacia Diagnostics AB 1994, CIS Bio International 1994, 1995).

Statistics

Data are described as means ± standard error of the means. To evaluate differences between run-in, treatment and run-out periods in the placebo group, one-way analysis of variance on ranks was performed. Differences within the prednisolone group were compared by one-way analysis of variance followed by Student–Newman–Keuls multiple range test. Intergroup comparisons were performed with Students’s \(t\)-test for unpaired samples if data fulfilled conditions for parametric analysis, otherwise the Mann–Whitney rank sum test was used. To assess whether the response of osteocalcin to prednisolone was the same for each assay the percentage change of prednisolone to run-in values was evaluated by the method described by Bland & Altman (1986). The 5% level of significance was used. All statistics were performed using the SOLO Statistical Software package (BMDP Statistical Software, Los Angeles, CA, USA).

Table 1 Characteristics of the osteocalcin assays

<table>
<thead>
<tr>
<th>Assay</th>
<th>Type</th>
<th>Antibody</th>
<th>Variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAP</td>
<td>FEIA</td>
<td>Antihuman OC, mAb</td>
<td>6.2 4.1</td>
</tr>
<tr>
<td>ELSA-OSTEO</td>
<td>Sandwich RIA</td>
<td>Antihuman OC, mAb</td>
<td>5.4 5.0</td>
</tr>
<tr>
<td>OSTK-PR</td>
<td>Competitive RIA</td>
<td>Rabbit anti-bovine OC</td>
<td>5.5 5.2</td>
</tr>
</tbody>
</table>

OC, osteocalcin; mAb, monoclonal antibody.

Results

Six males and three females (age range (mean): 27–44 (33) years) were allocated to treatment with prednisolone, and six males and five females (19–45 (29) years) were allocated to placebo treatment. Height, weight and body surface area (range (mean)) were 161–184 (174) cm, 60–81 (69) kg, 1.7–2.0 (1.8) m\(^2\) in the prednisolone group, and 165–200 (177) cm, 57–114 (72) kg, 1.6–2.5 (1.9) m\(^2\) in the placebo group. There were no significant demographic differences between the groups. Compliance with dosage regimen was 100% in both groups during all periods. The treatment blood sample from one male in the placebo group was lost, and a male in the prednisolone group forgot his run-out appointment and, therefore, did not have blood collected during that period.

Individual values of serum concentrations of osteocalcin during run-in, treatment and run-out are shown in Fig. 1. All data showed a Gaussian distribution. Group means and the results of intra- and intergroup comparisons are given in Table 2. The intra-group comparisons show that prednisolone treatment was associated with a statistically significant suppression of osteocalcin which was detected by all assays. Furthermore, osteocalcin values returned to pretreatment levels during run-out. In the placebo group osteocalcin levels were constant throughout all periods. The results of the intergroup analyses based on each assay were consistent with the intra-group comparisons. Figure 2 shows the plots of the pairwise comparisons of the CAP FEIA, OSTK-PR and ELSA-OSTEO assays respectively, in the prednisolone-treated group based on the percentage of prednisolone to run-in values in all subjects. In the individual subjects the response to prednisolone was similar for each assay.
Discussion

Most of the commercially available osteocalcin assays are based on radioimmunoassay techniques some of which use polyclonal, others monoclonal antibodies (Delmas et al. 1990, Diaz Diego et al. 1994, Garnero et al. 1994, Masters et al. 1994, Blumsohn et al. 1995, Cecchettin et al. 1995). The OSTK-PR assay applies polyclonal antibodies raised against bovine osteocalcin. It is the most widely used reference. We, therefore, compared this and an assay which applies monoclonal antibodies raised against human osteocalcin, the ELSA-OSTEO assay, with the recently introduced fluorescence immunoassay based on immunoCAP technology using monoclonal antibodies raised against human osteocalcin.

The absolute osteocalcin values determined by different assays may depend on assay type (RIA, FEIA), standardisation (human, bovine), antibody type (monoclonal, polyclonal), calcium dependency (Tracy et al. 1990), sensitivity, recovery, precision and specificity of the assay (human, bovine, intact osteocalcin molecule, C-terminal end of the molecule) (Delmas et al. 1990). Different assays may measure different fragments of the osteocalcin polypeptide (Deftos et al. 1992). In the ELSA-OSTEO assay the antibody tracer is directed against part of the osteocalcin molecule whereby intact osteocalcin as well as degradation products may be measured (Diaz Diego et al. 1994). A combination of one or more of the above-mentioned factors may explain why higher values were detected by the ELSA-OSTEO assays compared with the CAP FEIA which detects intact osteocalcin only (Kabi Pharmacia Diagnostics AB 1994). The epitopes bound by the antiserum used in the OSTK-PR assay have not been described and further studies addressing specificity and reactivity of osteocalcin assays are needed before these interassay variations can be fully understood. The results of the present study, however, confirm the reliability of the CAP FEIA for determination of serum osteocalcin in glucocorticoid-treated subjects. During prednisolone treatment reduced osteocalcin levels were detected by all assays in each patient and overall. So, although the degree of suppression may vary between assays and may confound osteocalcin data in patients with various bone disorders (Masters et al. 1994), the CAP FEIA, OSTK-PR and ELSA-OSTEO assays seem equally reliable for evaluation of osteocalcin in group studies of exogenous glucocorticoids.

Besides dose, the degree of suppression of serum concentrations of osteocalcin observed in individuals during glucocorticoid treatment may depend on several factors.

Figure 1 Run-in, treatment and run-out serum concentrations of osteocalcin measured with the CAP FEIA, OSTK-PR and ELSA-OSTEO assays in 11 subjects treated with placebo (upper panel) and 9 subjects treated with prednisolone 20 mg twice daily (lower panel).
such as individual variations in metabolism and sensitivity to exogenous glucocorticoids, concurrent administration of topical glucocorticoids, potency of the drug used and administration regimen (Reid 1989, Wolthers et al. 1993, Knutsson et al. 1995, Morice et al. 1996). Long term treatment is associated with a significant risk of osteopenia (Reid 1989). To reduce the risk in many conditions short term treatment regimens are used (Toogood & Hodsman 1991, Lems et al. 1993, Wolthers et al. 1996). Since an exponential decline in bone mass has been found with the highest bone loss within 6 months of treatment and a much slower rate of loss after 12 months of treatment (LoCascio et al. 1990), short term evaluations of bone turnover focusing specifically on the relation between duration of treatment and duration of possible adverse effects on bone turnover are needed. In the present study we wanted to assess an administration regimen which is used in a variety of conditions (Toogood & Hodsman 1991, Lems et al. 1993, Wolthers et al. 1996).

### Table 2 Serum concentrations (g/l) of osteocalcin (group means ± S.E.M.) based on the CAP FEIA, OSTK-PR and ELSA-OSTEO assays and intra- and intergroup comparisons (P values) in 11 subjects treated with placebo and 9 subjects treated with prednisolone (20 mg twice daily).

<table>
<thead>
<tr>
<th></th>
<th>CAP FEIA</th>
<th>OSTK-PR</th>
<th>ELSA-OSTEO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Placebo group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run-in (n=11)</td>
<td>7.55 ± 1.17</td>
<td>9.45 ± 1.07</td>
<td>28.64 ± 3.92</td>
</tr>
<tr>
<td>Treatment (n=10)</td>
<td>7.41 ± 1.49</td>
<td>9.53 ± 1.31</td>
<td>29.42 ± 4.82</td>
</tr>
<tr>
<td>Run-out (n=11)</td>
<td>8.57 ± 1.40</td>
<td>10.21 ± 1.14</td>
<td>29.34 ± 4.18</td>
</tr>
<tr>
<td><strong>Prednisolone group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run-in (n=9)</td>
<td>6.10 ± 0.64</td>
<td>8.63 ± 0.83</td>
<td>22.41 ± 1.89</td>
</tr>
<tr>
<td>Treatment (n=9)</td>
<td>2.00 ± 0.31</td>
<td>2.96 ± 0.43</td>
<td>7.71 ± 1.10</td>
</tr>
<tr>
<td>Run-out (n=8)</td>
<td>6.33 ± 0.87</td>
<td>8.19 ± 1.08</td>
<td>20.64 ± 2.55</td>
</tr>
<tr>
<td><strong>Placebo vs prednisolone group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run-in</td>
<td>0.32</td>
<td>0.57</td>
<td>0.32**</td>
</tr>
<tr>
<td>Treatment</td>
<td>&lt;0.0001**</td>
<td>&lt;0.0005</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Run-out</td>
<td>0.23</td>
<td>0.23</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Statistical comparisons</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANOVA</td>
<td></td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Run-in vs treatment</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Treatment vs run-out</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Run-in vs run-out</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

*ANOVA on ranks; **Mann–Whitney rank sum test.
NS, not significant.

![Figure 2](image.jpg)

**Figure 2** Means (x axis) and differences (y axis), expressed as percentages of run-in levels, of pairwise comparisons of osteocalcin values assessed by the CAP FEIA, OSTK-PR and ELSA-OSTEO assays during prednisolone treatment. The different marks identify the 9 individual subjects in each panel.
1991). Our findings are in accord with reports that prednisone and prednisolone 20 mg twice daily for 5 and 10 days respectively, are associated with suppressed osteocalcin levels (Nielsen et al. 1988b, Hodsman et al. 1991, Lane et al. 1996). The duration of suppression of osteocalcin after a single administration of 10 mg prednisone seems to be approximately 16 h (Nielsen et al. 1988a). The duration of suppression after withdrawal of several days of treatment, however, has not previously been assessed. This is an important factor to consider since a cumulative suppressive effect may play a key role in the early and rapid bone loss which occurs during treatment with exogenous corticosteroids (Reid 1989, LoCascio et al. 1990, Worth et al. 1994). The present findings have provided evidence that 4 days after withdrawal of a 3-day course of prednisolone (20 mg twice daily) bone turnover is unaffected. So, the risk of long term effects of short term treatment can be ignored. The risk of a suppressive effect on bone turnover from intermittent short term treatment with exogenous glucocorticoids, however, may need further evaluation in the intermediate and long term perspectives.

References


Cis Bio International 1995. OSTK-PR. Gif-Sur-Yvette Cedex, France.


Kabi Pharmacia Diagnostics AB 1994 Pharmacia CAP system osteocalcin FEIA. Uppsala, Sweden: Kabi Pharmacia Diagnostics AB.


Received 1 December 1997
Revised manuscript received 30 April 1998
Accepted 29 May 1998