

## THE QUANTITATIVE DETERMINATION OF RISEDRONATE IN URINE BY SPE-LC-MS-MS

### FIELD OF THE INVENTION

The present invention is directed to a SPE-LC-MS-MS method for quantitatively determining risedronate in a urine sample.

### BACKGROUND OF THE INVENTION

Bisphosphonates inhibit bone resorption and are effective treatments for metabolic bone diseases including osteoporosis and Paget's disease (I. Elomaa, C. Blomqvist, L. Porkka, T. Holmstrom, T. Taube, C. Larnberg-Allardt, G.H. Borgstrom, *Lancet* 1985; i:1155; J.P. Kosonen, *J. Pharm Biomed Anal.* 1992; 10:881; J.A. Cantril, H.M. Buckler, D.C. Anderson, *Ann. Rheumatol. Dis.* 1986; 45:1012; H.Fleisch, *Horm. Metab. Res.* 1997; 29:145). The prevention of bone resorption results from inhibitory effects on the function of mature osteoclasts. Several bioanalytical methods have been published for bisphosphonates. In general, those methods are mainly based on ion-exchange and ion-pair chromatography with UV, fluorescence (with a pre or post column derivatization), conductivity, flame photometric phosphorus selective, refractive index and explorative light-scattering detection (V. Virtanen, L.H.J. Lajunen, *J. Chromatogr.* 1993; 617:291; V. Virtanen, L.H.J. Lajunen, *Talanta* 1993; 40: 661; S.E. Meek, D.J. Pietrzyk *Anal. Chem.* 1988; 60:1397; M.J. Lovdahl, D.J. Pietrzyk, *J. Chromatogr. A* 1999; 850:143; R. Niemi, H. Taipale, M. Ahlmark, J. Vepsäläinen, T. Jarvinen, *J. Chromatogr. B* 1997; 701:97; T.L. Chester, *Anal. Chem.* 1980; 52:1621).

The technique of GC-MS, combined with acylation and silylation, has been used to determine Risedronate in human urine (D.Y. Mitchell, R.A. Eusebio, L.E. Dunlap, K.A. Pallone, J.D. Nesbitt, D.A. Russell, M.E. Clay, P.J. Becker, *Pharm. Res.* 1998; 15:228). The more sensitive method for analysis of Risedronate in human urine has been achieved using enzyme linked immunosorbent assay (ELISA) (D.Y. Mitchell, M.A. Heise, K.A. Pallone, J.D. Nesbitt, M.E. Clay, J.D. Nesbitt, D.A. Russell, C.W. Melson, *J. Clin. Pharmacol.* 1999; 48:536). The column-switching ion-pair HPLC with UV detection has also been reported to quantify the Risedronate in human urine (P.T. Vallano, S.B. Shugars, W.F. Kline, E.J. Woolf, B.K. Matuszewski, *J. Chromatogr. B* 1003; 794:23). Although some of these methods showed a very high sensitivity, they are all very complicated and time-consuming.

Recently, more effort has been put on the development of LC/MS/MS method for risedronate with post-extraction or on cartridge derivatization (L.S. Zhu, V.N. Lapko, J.W.

Lee, Y.J. Basir, C. Kafonek, R. Olsen, C. Briscoe, Rapid commun. Mass Spectrom. 2006, 20: 3421; S.Turcotte, J. Couture, F. Vallee, AAPS PharmSci Vol. 5, No. 4, Abstract M1357 (2003).

**SUMMARY OF THE INVENTION**      The present invention is directed to a method for quantitatively determining risedronate in a urine sample comprising:

- a) adding an internal standard to the urine sample;
- b) applying the urine sample to an Oasis HLB cartridge, wherein the cartridge has been pre-conditioned with methanol;
- c) washing the cartridge with about 1% (v/v) TEA in water and about 1% (v/v) formic acid in methanol;
- d) eluting risedronate, at least once, with a mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA under vacuum;
- e) evaporating the eluted solution and reconstituting with a mixture of 10% (v/v) methanol and 90% (v/v) 0.05 M NH<sub>4</sub>Ac-NH<sub>4</sub>OH buffer to provide a sample mixture of risedronate and the internal standard; and
- f) analyzing the sample mixture with a LC-MS/MS system.

The aforesaid SPE-LC-MS-MS method for quantitative determination of risedronate in a urine sample is relatively simple, sensitive, precise and accurate, and more fully discussed with the aid of the following figures and detailed description below.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

**FIGURE 1** is the ESI-MS Spectrum of Risedronate.

**FIGURE 2** is the ESI-MS Spectrum of Deoxy-risedronate.

**FIGURE 3** is the Chromatogram of Risedronate in Mouse Urine (LLOQ 10 ng/mL), wherein the intensity of the peak at retention of 2.27 minute is more than three times of the intensity of the same peak in the HPLC Spectrum of Blank Mouse Urine Sample. This means that the risedronate concentration at 10 ng/mL in mouse urine can be quantified.

**FIGURE 4** is the Chromatogram of Mouse Control Urine.

**FIGURE 5** is the Typical Chromatogram of Risedronate and Deoxy-Risedronate.

**FIGURE 6** is the Typical Calibration Curve of Risedronate in Mouse Urine.

## DETAILED DESCRIPTION OF THE INVENTION

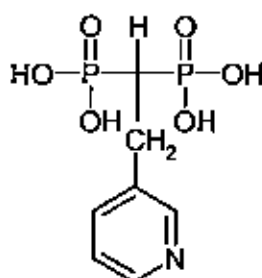
### Definitions and Abbreviations

As used above, and throughout the description of the invention, the following abbreviations, unless otherwise indicated, shall be understood to have the following meanings:

|                    |                                                                                    |
|--------------------|------------------------------------------------------------------------------------|
| amu                | Atom mass unit                                                                     |
| Cps                | Count per second                                                                   |
| CV%                | Percent coefficient of variation                                                   |
| Diff%              | Percentage difference between theoretical concentration and measured concentration |
| EDTA               | Ethylenediaminetetraacetic acid                                                    |
| ESI                | Electrical Spray Ionization                                                        |
| HPLC               | High Pressure Liquid Chromatography                                                |
| LC-MS              | High Pressure Liquid Chromatography-Mass Spectrometry                              |
| LLOQ               | Lower limit of quantity                                                            |
| MRM                | Multiple reaction monitoring                                                       |
| MS                 | Mass Spectrometry                                                                  |
| m/z                | Mass/charge                                                                        |
| NH <sub>4</sub> Ac | Ammonium acetate                                                                   |
| NH <sub>4</sub> OH | Ammonium hydroxide                                                                 |
| SD                 | Standard deviation                                                                 |
| SPE                | Solid phase extraction                                                             |
| TEA                | Triethylamine                                                                      |
| v/v                | Volume/volume                                                                      |

As used above, and throughout the description of the invention, the following terms, unless otherwise indicated, shall be understood to have the following meanings.

"Deoxy-Risedronate" means (1-phosphono-2-pyridin-3-yl-ethyl)-phosphonic acid, having the following chemical structure:

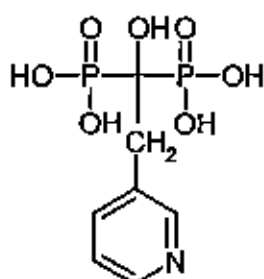


"Inertsil Phenyl-3 HPLC column" is manufactured and sold by Varian, Inc.

"Internal standard" is a chemical substance that is added in a constant amount to samples, blank and calibration standards in an analysis. This chemical substance is used for calibration by plotting the ratio of the analyte signal to the internal standard signal as a function of the analyte concentration of the standards. This is done to measure and correct for the loss of analyte during sample preparation or sample inlet. Particularly, the internal standard is a compound that has similar, but not same, chemical structure to the analyte.

"Oasis HLB cartridge" is manufactured and sold by Waters Corporation. The size of the cartridge is dependent upon the risedronate concentration in the urine sample. The lower risedronate concentration the urine sample has, the bigger size of the cartridge, and the larger volume of urine sample and the solution to wash the cartridge and elute risedronate should be used.

"Risedronate" means (1-hydroxy-1-phosphono-2-pyridin-3-yl-ethyl)-phosphonic acid, having the following chemical structure:



"Urine sample" means mammalian urine sample, including human urine sample.

#### Particular Embodiment of the Invention

One particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the urine sample is a mouse or rat urine sample.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the internal standard is deoxy-risedronate.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the Oasis HLB cartridge is a 30 mg Oasis HLB cartridge.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the internal standard is deoxy-risedronate that is added as a solution in water; more particularly as an about 10 µg/mL solution in water.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the amount of the urine sample is about 0.4 mL.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the cartridge has been pre-conditioned with about 1 mL of methanol.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the cartridge has been pre-conditioned with about 1 mL of methanol and followed by about 0.5 mL of 1% (v/v) TEA in water.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the cartridge is washed with about 0.5 mL of about 1% (v/v) TEA in water and about 0.5 mL of about 1% (v/v) formic acid in methanol.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the amount of the mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA is about 1.5 mL.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein risedronate is eluted twice with about 0.75 mL of the mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the amount of the mixture of 10% (v/v) methanol and 90% (v/v) 0.05 M NH<sub>4</sub>Ac-NH<sub>4</sub>OH buffer is about 100 µL.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a urine sample, wherein the internal standard is deoxy-risedronate, and analyzing the sample mixture with a LC-MS/MS system comprises separating risedronate

and deoxy-risedronate by HPLC on an Inertsil Phenyl-3 HPLC column by gradient elution with a mixture of solution A and solution B, wherein the amount of solution A is increased from about 10% (v/v) to about 95% (v/v), and wherein the solution A is about 90% (v/v) methanol in water, and solution B is about 10 mM ammonium acetate-acetic acid buffer with 2% (v/v) triethylamine.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a mouse or rat urine sample, comprising:

- a) adding about 100  $\mu$ L of about 10  $\mu$ g/mL dexoy-risedronate solution in water to about 0.4 mL of the mouse or rat urine sample;
- b) applying the mouse or rat urine sample to a 30 mg Oasis HLB cartridge, wherein the cartridge has been pre-conditioned with about 1 mL of methanol and followed by about 0.5 mL of 1% (v/v) TEA in water;
- c) washing the cartridge with about 0.5 mL of 1% (v/v) TEA in water and about 0.5 mL of 1% (v/v) formic acid in methanol;
- d) eluting risedronate with about 1.5 mL of a mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA under vacuum;
- e) evaporating the eluted solution and reconstituting with about 100  $\mu$ L of a mixture of about 10% (v/v) of methanol and about 90% (v/v) of about 0.05 M  $\text{NH}_4\text{Ac}$ - $\text{NH}_4\text{OH}$  buffer to provide a sample mixture of risedronate and dexoy-risedronate; and
- f) analyzing the sample mixture with a LC-MS/MS system, wherein risedronate and dexoy-risedronate are separated by HPLC on an Inertsil Phenyl-3 HPLC column by gradient elution with a mixture of solution A and solution B, wherein the amount of solution A is increased from about 10% (v/v) to about 95% (v/v), and wherein the solution A is about 90% (v/v) methanol in water, and solution B is about 10 mM ammonium acetate-acetic acid buffer with 2% (v/v) triethylamine.

Another particular embodiment of the invention is the method for quantitatively determining risedronate in a mouse or rat urine sample, comprising:

- a) adding about 100  $\mu$ L of about 10  $\mu$ g/mL dexoy-risedronate solution in water to about 0.4 mL of the mouse or rat urine sample;
- b) applying the mouse or rat urine sample to a 30 mg Oasis HLB cartridge, wherein the cartridge has been pre-conditioned with about 1 mL of methanol and followed by about 0.5 mL of 1% (v/v) TEA in water;

- c) washing the cartridge with about 0.5 mL of 1% (v/v) TEA in water and about 0.5 mL of 1% (v/v) formic acid in methanol;
- d) eluting risedronate twice with about 0.75 mL of a mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA under vacuum;
- e) evaporating the eluted solution and reconstituting with about 100  $\mu$ L of a mixture of about 10% (v/v) of methanol and about 90% (v/v) of about 0.05 M  $\text{NH}_4\text{Ac}$ - $\text{NH}_4\text{OH}$  buffer to provide a sample mixture of risedronate and dexoy-risedronate; and
- f) analyzing the sample mixture with a LC-MS/MS system, wherein risedronate and dexoy-risedronate are separated by HPLC on an Inertsil Phenyl-3 HPLC column by gradient elution with a mixture of solution A and solution B, wherein the amount of solution A is increased from about 10% (v/v) to about 95% (v/v), and wherein the solution A is about 90% (v/v) methanol in water, and solution B is about 10 mM ammonium acetate-acetic acid buffer with 2% (v/v) triethylamine.

It is to be understood that this invention covers all appropriate combinations of the particular embodiments referred thereto.

The present invention will appear more clearly from the following example that is presented as an illustration only and is not to be considered as limiting the invention in its scope.

#### **EXAMPLE**

##### **Step 1: Preparation of Risedronate Urine Standards in Mouse or Rat Urine**

A 1 mg/mL risedronate stock solution is prepared by dissolving risedronate in HPLC grade water. 250  $\mu$ g/mL, 100  $\mu$ g/mL and 50  $\mu$ g/mL risedronate standard solutions are prepared by diluting 250  $\mu$ L, 100  $\mu$ L and 50  $\mu$ L of the 1 mg/mL risedronate stock solution to 1 mL with HPLC grade water, respectively. Appropriate dilutions of 250  $\mu$ g/mL, 100  $\mu$ g/mL and 50  $\mu$ g/mL risedronate standard solutions are performed to yield risedronate working solutions of 25  $\mu$ g/mL, 10  $\mu$ g/mL, 5  $\mu$ g/mL, 2.5  $\mu$ g/mL and 1  $\mu$ g/mL. Risedronate urine standards, ranging from 10 ng/mL to 2500 ng/mL, are prepared by adding 4  $\mu$ L of each working solution into 0.4 mL of mouse or rat control urine (i.e., urine from mouse or rat that is not dosed with risedronate).

##### **Step 2: Sample Preparation**

A 0.4 mL urine sample collected from mouse or rat that has been dosed with risedronate is transferred to a 10x75 mm glass culture tube. 100  $\mu$ L of stock internal standard

solution, i.e., 10 µg/mL deoxy-risedronate solution in water, and 100 µL of 5% TEA in water are added to all the risedronate urine standards and the urine sample, respectively.

Sample extraction is performed with a 30 mg Oasis HLB cartridge (1 mL, manufactured and sold by Waters Corporation, Catalog No.: WAT094225). The cartridges are conditioned with 1 mL methanol and followed by 0.5 mL of 1% TEA in water. The urine sample is applied to the cartridge. The cartridge is washed with 0.5 mL of 1% TEA in water and 0.5 mL of 1% formic acid in methanol, and then the analyte and the internal standard are eluted using two consecutive elution steps with 0.75 mL of a mixture of 60% methanol in water containing 3 mM EDTA. During the samples extraction, a vacuum (5-15 Psi) is used at each step to pull the liquid through the cartridges. The eluted solution is dried under nitrogen at 37°C for 70 minutes and then the residue is reconstituted in 100 µL of 10% methanol/90% 0.05 M NH<sub>4</sub>Ac-NH<sub>4</sub>OH buffer (pH 9.26).

### **Step 3: LC-MS/MS analysis**

The analysis of Risedronate is performed using API 4000 LC-MS/MS system (sold by MDS Sciex), including a Shimadzu LC-10AD pump, SCL-10A VP system controller, Leap Technologies HTS PAL autosampler and API 4000 triple quadrupole mass-spectrometer.

Risedronate and the internal standard are separated on an Inertsil Phenyl-3 HPLC column (3 µL, 50x 030 mm, manufactured and sold by Varian, Inc., Catalog No.: 0408-050x030) by gradient elution with a mixture of solution A and solution B in 6 minutes, wherein the amount of solution A is increased from 10% to 95%. The solution A is 90% methanol in water, and the solution B is 10 mM ammonium acetate-acetic acid buffer (pH=5.0) with 2% triethylamine. The flow rate is kept constant at 0.2 mL/min. The sample (10 µL reconstitute) is injected onto the HPLC column directly. The mass spectrometer is programmed to monitor the transition  $m/z$  281.9→63.1 for risedronate under negative mode with a collision energy of -58 volts. The  $m/z$  265.8→79.2 is used to measure deoxy-Risedronate internal standard. The source temperature is set at 350°C. An analytical run time of 6 minutes is employed.

## **Results**

### **Linearity**

The assay for risedronate mouse or rat urine standard is linear from 10 to 2500 ng/mL with an LLOQ of 10 ng/mL. The determined accuracy at LLOQ is 14.8% with a precision of 17.8% (n=3). The regression parameters obtained during the validation are reported in table 1.

Correlation coefficients of 0.98 or greater for risedronate are obtained from the day-to-day analysis. A typical calibration curve is represented in FIGURE 6.

**Table 1. Regression parameters for risedronate in mouse urine**

| Curve No/Date     | Regression Parameters             |                                               |                            |
|-------------------|-----------------------------------|-----------------------------------------------|----------------------------|
|                   | Slope<br>(response/concentration) | Intercept<br>(response at<br>concentration 0) | Correlation<br>Coefficient |
| <b>Within-day</b> |                                   |                                               |                            |
| #1                | 0.000260                          | 0.00208                                       | 0.9993                     |
| #2                | 0.000257                          | 0.00151                                       | 0.9961                     |
| #3                | 0.000232                          | 0.00300                                       | 0.9895                     |
|                   |                                   |                                               |                            |
| Mean              | 0.000250                          | 0.00220                                       | 0.9950                     |
| SD                | 0.000015                          |                                               |                            |
| CV%               | 6.2                               |                                               |                            |
|                   |                                   |                                               |                            |
| <b>Day-to-day</b> |                                   |                                               |                            |
| Day 1             | 0.000267                          | 0.00331                                       | 0.997                      |
| Day 2             | 0.000229                          | 0.000594                                      | 0.9974                     |
| Day 3             | 0.000260                          | 0.00208                                       | 0.9993                     |
|                   |                                   |                                               |                            |
| Mean              | 0.000252                          | 0.00199                                       | 0.9979                     |
| SD                | 0.000020                          |                                               |                            |
| CV%               | 8.0                               |                                               |                            |

### ***Specificity***

A small peak, at retention time of 2.27, is found in mouse control urine, but the peak height of LLOQ (10 ng/mL) is more than three times of the intensity of the peak in the mouse control urine (see FIGURE 3 and FIGURE 4). Thus, risedronate concentration at 10 ng/mL can be quantified.

### ***Precision***

Precision is expressed as the percent coefficient of variation of the concentrations measured at each control level over the duration of the study. The within-day coefficient of variation for the controls in mouse urine ranged from 2.2 to 9.6%. The day-to-day precision

for the controls at 3 concentration levels ranged from 5.2 to 10.3 %. The within-day and the day-to-day precisions for the standards ranged from 0.3 to 26%.

***Accuracy***

The assay accuracy is expressed as the percent difference between the mean determined quality control concentration and the theoretical value.

The within-day assay accuracy for the mouse urine controls ranged from -5.3 to 4.4 %. The day-to-day accuracy is determined over three analysis days using the controls at 3 concentration levels. The day-to-day accuracy ranged from -4.0 to 6.0%. The accuracy from the back-calculated concentrations of the mouse urine standards is within  $\pm 15\%$ .

**Table 2. The accuracy and precision of mouse urine calibration standards of risedronate**

| Replicate<br>Or date | Nominal Concentration (ng/mL) |      |      |      |      |       |       |       |
|----------------------|-------------------------------|------|------|------|------|-------|-------|-------|
|                      | 10                            | 25   | 50   | 100  | 250  | 500   | 1000  | 2500  |
| <b>Within-day</b>    |                               |      |      |      |      |       |       |       |
| #1                   | 7.93                          | 20.7 | 49.4 | 100  | 237  | 422   | 995   | 2460  |
| #2                   | 13.3                          | 22   | 42.8 | 91.6 | 238  | 388   | 868   | 2470  |
| #3                   | 9.94                          | 25.4 | 50.6 | 97   | 253  | 476   | 976   | 2500  |
|                      |                               |      |      |      |      |       |       |       |
| Mean                 | 10.39                         | 22.7 | 47.6 | 96.2 | 243  | 429   | 946   | 2477  |
| SD                   | 2.71                          | 2.43 | 4.20 | 4.26 | 8.96 | 44.38 | 68.50 | 20.82 |
| CV%                  | 26.1                          | 10.7 | 8.8  | 4.4  | 3.7  | 10.4  | 7.2   | 0.8   |
| Diff%                | 3.9                           | -9.2 | -4.8 | -3.8 | -2.9 | -14.3 | -5.4  | -0.9  |
|                      |                               |      |      |      |      |       |       |       |
| <b>Day-to-day</b>    |                               |      |      |      |      |       |       |       |
| Day 1                | 13.8                          | 24.7 | 46.9 | 93.5 | 237  | 532   | 1120  | 2610  |
| Day 2                | 10.7                          | 21.5 | 50.6 | 107  | 248  | 501   | 1010  | 2640  |
| Day 3                | 9.94                          | 25.4 | 50.6 | 97   | 253  | 476   | 976   | 2500  |
|                      |                               |      |      |      |      |       |       |       |
| Mean                 | 11.48                         | 23.9 | 49.4 | 99.2 | 246  | 503   | 1035  | 2583  |
| SD                   | 2.04                          | 2.08 | 2.14 | 7.01 | 8.19 | 28.05 | 75.27 | 73.71 |
| CV%                  | 17.8                          | 8.7  | 4.3  | 7.1  | 3.3  | 5.6   | 7.3   | 2.9   |
| Diff%                | 14.8                          | -4.5 | -1.3 | -0.8 | -1.6 | 0.6   | 3.5   | 3.3   |

**Table 3. The accuracy and precision of mouse urine quality controls of risedronate**

| Date                      | Nominal Concentration (ng/mL) |       |      |
|---------------------------|-------------------------------|-------|------|
|                           | 25                            | 250   | 2500 |
| Day 1                     | 28.2                          | 257   | 2900 |
|                           | 30                            | 290   | 2580 |
|                           | 26.1                          | 236   | 2870 |
|                           |                               |       |      |
| Day 2                     | 28.9                          | 226   | 2650 |
|                           | 27.2                          | 208   | 2800 |
|                           | 25.5                          | 238   | 2470 |
|                           |                               |       |      |
| Day 3                     | 27.1                          | 244   | 2650 |
|                           | 24.1                          | 246   | 2670 |
|                           | 24.4                          | 231   | 2520 |
|                           | 23.8                          | 204   | 2600 |
|                           | 20.6                          | 259   | 2610 |
|                           |                               |       |      |
| <b>Within-day (Day 3)</b> |                               |       |      |
| Mean                      | 24.0                          | 237   | 2610 |
| SD                        | 2.31                          | 20.8  | 57.9 |
| CV %                      | 9.6                           | 8.8   | 2.2  |
| Diff %                    | -4                            | -5.28 | 4.4  |
|                           |                               |       |      |
| <b>Day-to-day</b>         |                               |       |      |
| Mean                      | 26.0                          | 240   | 2665 |
| SD                        | 2.69                          | 24.1  | 138  |
| CV%                       | 10.3                          | 10.1  | 5.2  |
| Diff%                     | 4.0                           | -4.0  | 6.6  |

#### ***Recovery***

A recovery of risedronate in extracted mouse urine as compared to extracted mouse urine blank with neat spiked is around 51.3%

**Table 4. Recovery of risedronate from mouse urine samples (250 ng/mL)**

| <b>Replicates</b>   | <b>Extracted Urine Sample<br/>(peak area)</b> | <b>Extracted Blank Urine<br/>Sample + spiked neat peak<br/>area</b> |
|---------------------|-----------------------------------------------|---------------------------------------------------------------------|
| #1                  | 12400                                         | 30400                                                               |
| #2                  | 18000                                         | 28800                                                               |
| #3                  | 16600                                         | 29800                                                               |
| #4                  | 18100                                         | 36000                                                               |
| #5                  | 14500                                         | 30300                                                               |
|                     |                                               |                                                                     |
| Mean                | 15920                                         | 31060                                                               |
| SD                  | 2447                                          | 2833                                                                |
| CV%                 | 15.4                                          | 9.1                                                                 |
|                     |                                               |                                                                     |
| <b>Recovery (%)</b> | <b>51.3</b>                                   |                                                                     |

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof.

We claim:

1. A method for quantitatively determining risedronate in a urine sample comprising:
  - a) adding an internal standard solution to the urine sample;
  - b) applying the urine sample to an Oasis HLB cartridge, wherein the cartridge has been pre-conditioned with methanol;
  - c) washing the cartridge with about 1% (v/v) TEA in water and about 1% (v/v) formic acid in methanol;
  - d) eluting risedronate, at least once, with a mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA under vacuum;
  - e) evaporating the eluted solution and reconstituting with a mixture of 10% (v/v) methanol and 90% (v/v) 0.05 M  $\text{NH}_4\text{Ac}$ - $\text{NH}_4\text{OH}$  buffer to provide a sample mixture of risedronate and the internal standard; and
  - f) analyzing the sample mixture with a LC-MS/MS system.
2. The method according to claim 1, wherein the urine sample is a mouse or rat urine sample.
3. The method according to claim 1, wherein the internal standard is deoxy-risedronate.
4. The method according to claim 1, wherein the internal standard is deoxy-risedronate that is added as a solution in water.
5. The method according to claim 1, wherein the internal standard is deoxy-risedronate that is added as an about 10  $\mu\text{g/mL}$  solution in water.
6. The method according to claim 1, wherein the Oasis HLB cartridge is a 30 mg Oasis HLB cartridge.
7. The method according to claim 1, wherein the amount of the urine sample is about 0.4 mL.
8. The method according to claim 1, wherein the cartridge has been pre-conditioned with about 1 mL of methanol.
9. The method according to claim 1, wherein the cartridge has been pre-conditioned with about 1 mL of methanol and followed by about 0.5 mL of 1% (v/v) TEA in water.
10. The method according to claim 1, wherein the cartridge is washed with about 0.5 mL of about 1% (v/v) TEA in water and about 0.5 mL of about 1% (v/v) formic acid in methanol.
11. The method according to claim 1, wherein the amount of the mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA is about 1.5 mL.

12. The method according to claim 1, wherein risedronate is eluted twice with about 0.75 mL of the mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA.
13. The method according to claim 1, wherein the amount of the mixture of 10% (v/v) methanol and 90% (v/v) 0.05 M  $\text{NH}_4\text{Ac}$ - $\text{NH}_4\text{OH}$  buffer is about 100  $\mu\text{L}$ .
14. The method according to claim 1, wherein the internal standard is dexoy-risedronate, and analyzing the sample mixture with a LC-MS/MS system comprises separating risedronate and dexoy-risedronate by HPLC on an Inertsil Phenyl-3 HPLC column by gradient elution with a mixture of solution A and solution B, wherein the amount of solution A is increased from about 10% (v/v) to about 95% (v/v), and wherein the solution A is about 90% (v/v) methanol in water, and solution B is about 10 mM ammonium acetate-acetic acid buffer with 2% (v/v) triethylamine.
15. A method for quantitatively determining risedronate in a mouse or rat urine sample, comprising:
  - a) adding about 100  $\mu\text{L}$  of about 10  $\mu\text{g/mL}$  dexoy-risedronate solution in water to about 0.4 mL of the mouse or rat urine sample;
  - b) applying the mouse or rat urine sample to a 30 mg Oasis HLB cartridge, wherein the cartridge has been pre-conditioned with about 1 mL of methanol and followed by about 0.5 mL of 1% (v/v) TEA in water;
  - c) washing the cartridge with about 0.5 mL of 1% (v/v) TEA in water and about 0.5 mL of 1% (v/v) formic acid in methanol;
  - d) eluting risedronate with about 1.5 mL of a mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA;
  - e) evaporating the eluted solution and reconstituting with about 100  $\mu\text{L}$  of a mixture of about 10% (v/v) of methanol and about 90% (v/v) of about 0.05 M  $\text{NH}_4\text{Ac}$ - $\text{NH}_4\text{OH}$  buffer to provide a sample mixture of risedronate and dexoy-risedronate; and
  - f) analyzing the sample mixture with a LC-MS/MS system, wherein risedronate and dexoy-risedronate are separated by HPLC on an Inertsil Phenyl-3 HPLC column by gradient elution with a mixture of solution A and solution B, wherein the amount of solution A is increased from about 10% (v/v) to about 95% (v/v), and wherein the solution A is about 90% (v/v) methanol in water, and solution B is about 10 mM ammonium acetate-acetic acid buffer with 2% (v/v) triethylamine.

16. A method for quantitatively determining risedronate in a mouse or rat urine sample, comprising:
- a) adding about 100  $\mu\text{L}$  of about 10  $\mu\text{g/mL}$  dexoy-risedronate solution in water to about 0.4 mL of the mouse or rat urine sample;
  - b) applying the mouse or rat urine sample to a 30 mg Oasis HLB cartridge, wherein the cartridge has been pre-conditioned with about 1 mL of methanol and followed by about 0.5 mL of 1% (v/v) TEA in water;
  - c) washing the cartridge with about 0.5 mL of 1% (v/v) TEA in water and about 0.5 mL of 1% (v/v) formic acid in methanol;
  - d) eluting risedronate twice with about 0.75 mL of a mixture of about 60% (v/v) methanol and about 40% (v/v) water containing about 3 mM EDTA;
  - e) evaporating the eluted solution and reconstituting with about 100  $\mu\text{L}$  of a mixture of about 10% (v/v) of methanol and about 90% (v/v) of about 0.05 M  $\text{NH}_4\text{Ac}$ - $\text{NH}_4\text{OH}$  buffer to provide a sample mixture of risedronate and dexoy-risedronate; and
  - f) analyzing the sample mixture with a LC-MS/MS system, wherein risedronate and dexoy-risedronate are separated by HPLC on an Inertsil Phenyl-3 HPLC column by gradient elution with a mixture of solution A and solution B, wherein the amount of solution A is increased from about 10% (v/v) to about 95% (v/v), and wherein the solution A is about 90% (v/v) methanol in water, and solution B is about 10 mM ammonium acetate-acetic acid buffer with 2% (v/v) triethylamine.