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TECHNICAL NOTE 65134

# Quantification of neuroleptics in human plasma or serum by liquid chromatography-tandem mass spectrometry for clinical research


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**Keywords**

Neuroleptics, offline sample preparation, plasma, serum, mass spectrometry


## Goal

Implementation of an analytical method for the quantification of 15 different neuroleptics in human plasma or serum on a Thermo Scientific™ TSQ Quantis™ triple quadrupole mass spectrometer

## Application benefits

- Simple offline sample preparation by protein precipitation
- 28 neuroleptics in a single quantitative method

## Introduction

An analytical method for clinical research, quantifying 28 neuroleptics in human plasma or serum, is reported. Analysis includes ziprasidone, paliperidone, flupenthixole, prothipendyl, aripiprazole, melperone, melperone, promethazine, levomepromazine, sulpiride, haloperidole, sertindole, perazine, zotepine, clozapine, risperidone, olanzapine, fluphenazine, dehydroaripiprazole, zuclopenthixole, pipamperone, norquetiapine, quetiapine, thioridazine, chlorprothixene, desmethylolanzapine, chlorpromazine, and norclozapine. Plasma or serum samples are extracted by offline internal standard addition and protein precipitation. Extracted samples are injected onto a Thermo Scientific™ Vanquish™ Flex Binary system connected to a Thermo Scientific™ TSQ Quantis™ triple quadrupole mass spectrometer with heated electrospray ionization. Detection is performed by selected reaction monitoring (SRM) using 25 deuterated internal standards. Method performance was evaluated using the ClinMass® TDM Platform with the ClinMass Add-On Set for Neuroleptics from RECIPE Chemicals + Instruments GmbH (Munich, Germany) to obtain limits of quantification, linearity ranges, accuracy, and intra- and inter-assay precision for each analyte.

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## Experimental

### Target analytes

The analytes and corresponding concentration ranges covered by the calibrators used are reported in Table 1.

**Table 1. Concentration ranges covered by calibrators**

| Analyte | Concentration (ng/mL) |
|---|---|
| Amisulpride | 36.1–721 |
| Aripiprazole | 54.7–1105 |
| Chlorpromazine | 17.7–375 |
| Chlorprothixene | 17.6–356 |
| Clozapine | 56.9–1185 |
| Dehydro-Aripiprazole | 9.85–191 |
| Desmethylolanzapine | 7.07–152 |
| Flupentixol | 0.622–13.1 |
| Fluphenazine | 0.605–12.6 |
| Haloperidol | 0.646–13 |
| Levomepromazine | 9.49–203 |
| Melperone | 10.4–212 |
| Norclozapine | 45.9–1020 |
| Norquetiapine | 9.16–185 |
| Olanzapine | 7.26–151 |
| Paliperidone | 6.67–136 |
| Perazine | 25.5–535 |
| Pipamperone | 30.9–636 |
| Promethazine | 20.4–406 |
| Prothipendyl | 1.06–22 |
| Quetiapine | 29.4–571 |
| Risperidone | 6.6–142 |
| Sertindole | 10.5–215 |
| Sulpiride | 55.6–1172 |
| Thioridazine | 20.5–475 |
| Ziprasidone | 17.5–350 |
| Zotepine | 8.73–178 |
| Zuclopenthixol | 3.66–77.8 |

### Sample preparation

Reagents included four calibrators (including blank) and two controls from RECIPE, as well as 25 deuterated internal standards for the quantification. Samples of 50 µL of plasma or serum were protein precipitated using 100 µL of precipitating solution containing the internal standards. Precipitated samples were vortex-mixed and centrifuged, and the supernatant was transferred to a clean plate or vial.

### Liquid chromatography

Chromatographic separation was achieved using mobile phases and analytical column provided by RECIPE. Details of the analytical methods are reported in Table 2. Total runtime was 6.0 minutes.

**Table 2. Liquid chromatographic method description**

Gradient profile:

| *Time (min)* | *Flow Rate (mL/min)* | *A (%)* | *B (%)* |
|---|---|---|---|
| 0.00 | 0.7 | 95 | 5 |
| 0.03 | 0.7 | 95 | 5 |
| 0.75 | 0.7 | 64 | 36 |
| 1.50 | 0.7 | 64 | 36 |
| 3.00 | 0.7 | 61 | 39 |
| 4.50 | 0.7 | 35 | 65 |
| 4.60 | 0.7 | 20 | 80 |
| 4.80 | 0.7 | 20 | 80 |
| 5.00 | 0.7 | 95 | 5 |
| 6.00 | 0.7 | 95 | 5 |

| | |
|---|---|
| Injection volume: | 10 µL |
| Column temp.: | 40 °C |

## Mass spectrometry

Analytes and internal standards were detected by SRM on a TSQ Quantis triple quadrupole mass spectrometer with heated electrospray ionization operated in positive mode. A summary of the MS conditions is reported in Table 3. Two SRM transitions for each analyte were included in the acquisition method for quantification and confirmation, respectively.

**Table 3. MS settings**

| | |
|---|---|
| Source type: | Heated electrospray ionization (HESI) |
| Vaporizer temperature: | 450 °C |
| Capillary temperature: | 325 °C |
| Spray voltage (positive mode): | 2500 V |
| Sheath gas: | 53 AU |
| Sweep gas: | 0 AU |
| Auxiliary gas: | 20 AU |
| Data acquisition mode: | Selected-reaction monitoring (SRM) |
| Collision gas pressure: | 1.5 mTorr |
| Cycle time: | 0.300 s |
| Q1 mass resolution (FWMH): | 0.7 |
| Q3 mass resolution (FWMH): | 0.7 |

## Method evaluation

The method performance was evaluated in terms of linearity of response within the calibration range, accuracy, and intra- and inter-assay precision for each analyte. Analytical accuracy was evaluated in terms of percentage bias between nominal and average back-calculated concentrations using quality control samples at two different levels provided by RECIPE (MS9313 batch #1346) prepared and analyzed in replicates of five on three different days. Intra-assay precision was evaluated for each day on the same set of runs (control samples at two levels, replicates of five each day, three days) in terms of percentage coefficient of variation (%CV). Inter-assay precision was evaluated on the same controls including all the 15 replicates of the three days.

## Data analysis

Data were acquired and processed using Thermo Scientific™ TraceFinder™ 4.1 software.

## Results and discussion

The method proved to be linear in the calibration ranges covered by the calibrators. Representative chromatograms for the lowest calibrator for quetiapine, clozapine, and their internal standards are reported in Figure 1. Representative calibration curves for the same analytes are reported in Figure 2.

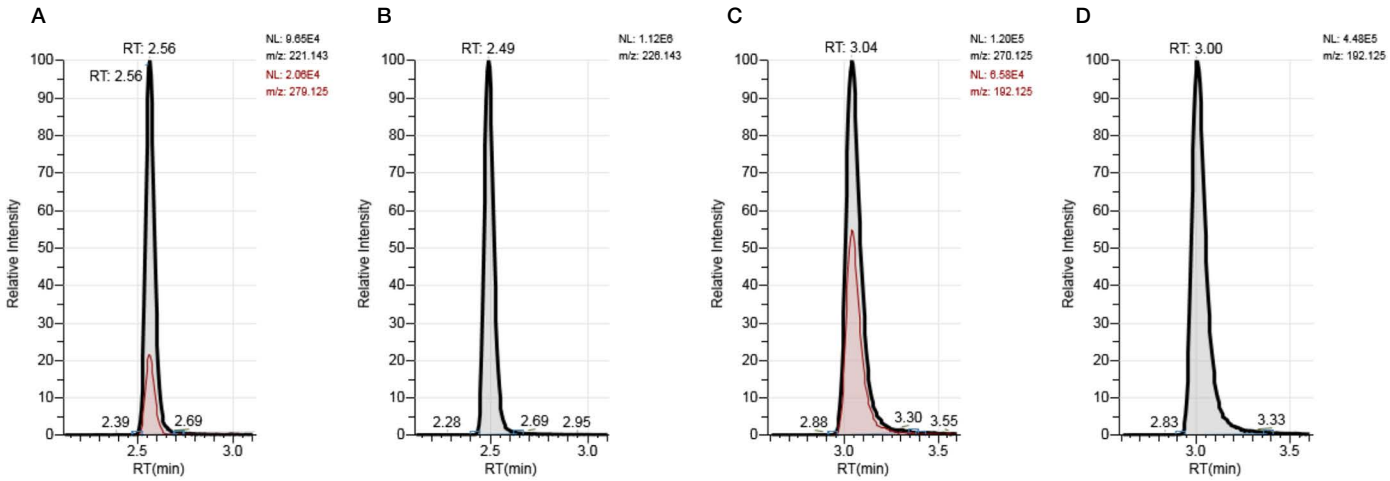


**Figure 1. Representative chromatograms of the lowest calibrator for (A) quetiapine, (B) d8-quetiapine, (C) clozapine, and (D) d4-clozapine.** Quetiapine and clozapine chromatograms show both the quantification (in black) and confirmation (in red) ions.

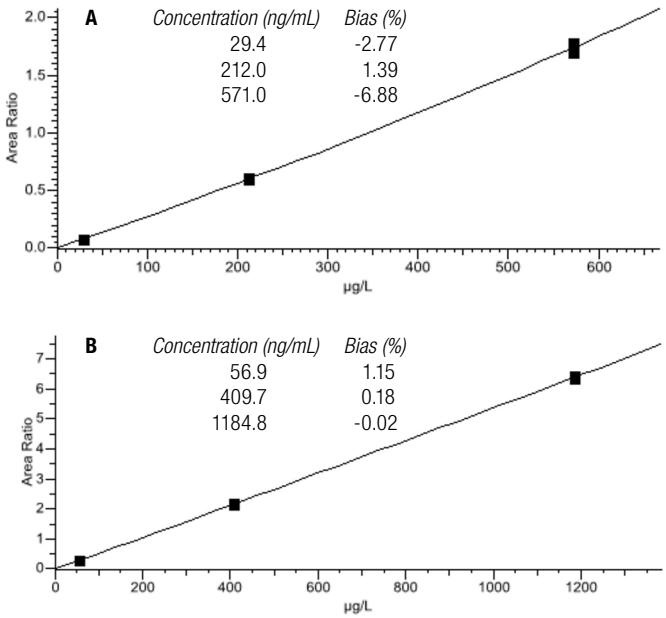


**Figure 2. Representative calibration curves for (A) quetiapine and (B) clozapine – day 1**

The data demonstrated outstanding accuracy of the method with the percentage bias between nominal and average back-calculated concentration for the control samples ranging between -7.8% and 6.8%. Results are reported in Table 4.

**Table 4. Analytical accuracy results for control MS9313 batch #1346**

| Analyte | Control 1 | | | Control 2 | | |
|---|---|---|---|---|---|---|
| | Nominal Concentration (ng/mL) | Average Calculated Concentration (ng/mL) | Bias (%) | Nominal Concentration (ng/mL) | Average Calculated Concentration (ng/mL) | Bias (%) |
| Aripiprazole | 216.0 | 207.5 | -3.9 | 494.0 | 505.5 | 2.3 |
| Chlorpromazine | 69.4 | 68.7 | -1.0 | 167.0 | 160.0 | -4.2 |
| Chlorprothixene | 66.0 | 68.7 | 4.0 | 156.0 | 164.3 | 5.3 |
| Clozapine | 224.0 | 221.0 | -1.3 | 524.0 | 522.8 | -0.2 |
| Dehydroaripiprazole | 37.4 | 35.6 | -4.9 | 86.8 | 80.0 | -7.8 |
| Desmethylolanzapine | 28.3 | 29.7 | 4.9 | 66.8 | 71.3 | 6.8 |
| Flupenthixole | 2.3 | 2.2 | -4.8 | 5.7 | 5.3 | -5.4 |
| Fluphenazine | 2.3 | 2.2 | -4.3 | 5.6 | 5.2 | -6.9 |
| Haloperidole | 2.5 | 2.5 | -1.3 | 6.1 | 5.7 | -6.4 |
| Levomepromazine | 36.8 | 37.9 | 2.9 | 89.2 | 91.4 | 2.4 |
| Melperone | 38.3 | 39.7 | 3.7 | 91.0 | 93.8 | 3.0 |
| Melperone | 38.3 | 39.7 | 3.7 | 91.0 | 93.8 | 3.0 |
| Norclozapine | 188.0 | 194.8 | 3.6 | 445.0 | 449.5 | 1.0 |
| Norquetiapine | 34.9 | 34.8 | -0.4 | 81.9 | 79.7 | -2.7 |
| Olanzapine | 28.0 | 29.2 | 4.3 | 66.5 | 66.4 | -0.1 |
| Paliperidone | 25.3 | 25.2 | -0.4 | 60.2 | 59.4 | -1.4 |
| Perazine | 99.4 | 97.9 | -1.5 | 233.0 | 230.0 | -1.3 |
| Pipamperone | 120.0 | 120.4 | 0.3 | 283.0 | 287.3 | 1.5 |
| Promethazine | 138.0 | 136.9 | -0.8 | 323.0 | 319.4 | -1.1 |
| Prothipendyl | 4.0 | 4.0 | 0.9 | 9.4 | 9.6 | 2.1 |
| Quetiapine | 117.0 | 117.2 | 0.2 | 269.0 | 268.0 | -0.4 |
| Risperidone | 25.5 | 24.6 | -3.6 | 58.1 | 58.8 | 1.3 |
| Sertindole | 40.9 | 40.2 | -1.6 | 96.1 | 94.9 | -1.3 |
| Sulpiride | 214.0 | 213.4 | -0.3 | 512.0 | 507.1 | -1.0 |
| Thioridazine | 81.4 | 80.7 | -0.9 | 199.0 | 198.0 | -0.5 |
| Ziprasidone | 65.2 | 67.4 | 3.4 | 157.0 | 158.5 | 0.9 |
| Zotepine | 34.1 | 32.4 | -4.9 | 78.0 | 74.2 | -4.8 |
| Zuclopenthixole | 14.6 | 13.6 | -7.0 | 33.4 | 31.9 | -4.5 |

The %CV for intra-assay precision was below 6.1% for all the analytes (Table 5). The maximum %CV for inter-assay precision including all the analytes was 9.4% (Table 6).

**Table 5. Intra-assay precision results**

| Analyte | Control 1 | | | | | | Control 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 1 | | Day 2 | | Day 3 | | Day 1 | | Day 2 | | Day 3 | |
| | Average Calculated Concentration (ng/mL) | CV (%) | Average Calculated Concentration (ng/mL) | CV (%) | Average Calculated Concentration (ng/mL) | CV (%) | Average Calculated Concentration (ng/mL) | CV (%) | Average Calculated Concentration (ng/mL) | CV (%) | Average Calculated Concentration (ng/mL) | CV (%) |
| Aripiprazole | 31.7 | 2.9 | 31.2 | 4.0 | 34.2 | 5.3 | 74 | 3.1 | 74 | 1.4 | 75 | 2.3 |
| Chlorpromazine | 36.5 | 1.4 | 37.1 | 4.7 | 39.8 | 3.2 | 90 | 1.3 | 92 | 1.9 | 91 | 3.3 |
| Chlorprothixene | 2.6 | 2.4 | 2.4 | 2.8 | 2.5 | 3.4 | 6 | 1.6 | 6 | 1.6 | 6 | 3.4 |
| Clozapine | 25.9 | 2.7 | 24.4 | 4.0 | 25.6 | 3.8 | 60 | 3.8 | 58 | 2.1 | 59 | 2.0 |
| Dehydroaripiprazole | 69.0 | 1.5 | 66.7 | 3.4 | 66.6 | 3.2 | 157 | 4.2 | 160 | 2.5 | 160 | 2.4 |
| Desmethylolanzapine | 39.4 | 4.5 | 38.2 | 2.4 | 41.8 | 2.0 | 94 | 4.1 | 90 | 1.0 | 96 | 1.3 |
| Flupenthixole | 39.4 | 4.5 | 38.2 | 2.4 | 41.8 | 2.0 | 94 | 4.1 | 90 | 1.0 | 96 | 1.3 |
| Fluphenazine | 227.7 | 4.2 | 204.9 | 3.9 | 232.9 | 0.8 | 531 | 3.6 | 504 | 1.6 | 531 | 2.3 |
| Haloperidole | 214.8 | 3.9 | 201.8 | 1.4 | 224.6 | 0.8 | 509 | 3.4 | 487 | 0.4 | 521 | 2.6 |
| Levomepromazine | 4.2 | 3.1 | 3.9 | 1.4 | 4.1 | 1.6 | 10 | 1.9 | 9 | 2.0 | 10 | 4.1 |
| Melperone | 40.1 | 3.4 | 38.0 | 3.5 | 42.8 | 0.8 | 96 | 4.1 | 92 | 2.8 | 97 | 2.8 |
| Melperone | 137.6 | 4.5 | 130.1 | 1.6 | 144.6 | 0.6 | 323 | 3.7 | 310 | 0.9 | 323 | 4.3 |
| Norclozapine | 25.6 | 4.0 | 22.7 | 2.5 | 25.6 | 1.6 | 59 | 3.4 | 56 | 2.5 | 61 | 3.1 |
| Norquetiapine | 82.0 | 3.0 | 73.6 | 2.8 | 86.8 | 1.7 | 201 | 4.1 | 188 | 1.2 | 203 | 2.9 |
| Olanzapine | 121.5 | 4.6 | 111.7 | 3.0 | 128.8 | 2.3 | 288 | 4.4 | 273 | 1.7 | 297 | 3.1 |
| Paliperidone | 119.1 | 3.7 | 107.1 | 3.4 | 125.7 | 1.4 | 269 | 2.6 | 254 | 1.6 | 279 | 3.6 |
| Perazine | 70.1 | 4.4 | 62.4 | 2.6 | 73.5 | 1.3 | 160 | 6.1 | 162 | 2.7 | 171 | 4.1 |
| Pipamperone | 190.4 | 2.7 | 176.7 | 3.2 | 216.2 | 2.2 | 445 | 3.2 | 425 | 3.3 | 477 | 1.8 |
| Promethazine | 28.8 | 1.7 | 27.3 | 2.5 | 31.5 | 1.9 | 66 | 3.4 | 62 | 3.0 | 71 | 2.1 |
| Prothipendyl | 202.7 | 3.4 | 203.9 | 3.7 | 216.4 | 1.6 | 476 | 2.5 | 542 | 3.0 | 490 | 1.9 |
| Quetiapine | 34.1 | 3.0 | 34.3 | 3.6 | 38.3 | 3.7 | 73 | 1.5 | 82 | 3.1 | 84 | 2.9 |
| Risperidone | 33.1 | 2.3 | 33.0 | 4.2 | 37.9 | 1.5 | 75 | 0.9 | 77 | 3.9 | 86 | 1.9 |
| Sertindole | 14.3 | 4.7 | 12.5 | 3.2 | 14.0 | 1.9 | 33 | 4.5 | 30 | 2.0 | 32 | 2.3 |
| Sulpiride | 2.4 | 3.6 | 2.1 | 3.0 | 2.3 | 3.4 | 5 | 3.3 | 5 | 2.7 | 5 | 2.7 |
| Thioridazine | 29.6 | 3.5 | 27.0 | 3.5 | 32.4 | 3.9 | 77 | 1.3 | 64 | 2.9 | 77 | 3.2 |
| Ziprasidone | 71.8 | 2.9 | 61.3 | 3.1 | 73.4 | 1.7 | 166 | 2.1 | 143 | 0.9 | 172 | 1.4 |
| Zotepine | 102.1 | 4.9 | 91.6 | 1.9 | 101.3 | 2.3 | 244 | 3.1 | 209 | 1.4 | 238 | 1.9 |
| Zuclopenthixole | 2.3 | 3.5 | 2.1 | 3.9 | 2.3 | 2.5 | 5 | 2.4 | 5 | 7.4 | 6 | 2.3 |

Table 6. Inter-assay precision results

| Analyte | Control 1 | | Control 2 | |
|---|---|---|---|---|
| | Average Calculated Concentration (ng/mL) | CV (%) | Average Calculated Concentration (ng/mL) | CV (%) |
| Aripiprazole | 32.4 | 5.9 | 74 | 2.2 |
| Chlorpromazine | 37.9 | 5.2 | 91 | 2.4 |
| Chlorprothixene | 2.5 | 5.3 | 6 | 2.5 |
| Clozapine | 25.2 | 3.9 | 59 | 2.5 |
| Dehydroaripiprazole | 67.4 | 3.2 | 158 | 2.9 |
| Desmethylolanzapine | 39.7 | 5.0 | 94 | 3.4 |
| Flupenthixole | 39.7 | 5.0 | 94 | 3.4 |
| Fluphenazine | 221.0 | 6.5 | 523 | 3.5 |
| Haloperidole | 213.4 | 5.2 | 507 | 3.7 |
| Levomepromazine | 4.0 | 4.1 | 10 | 3.8 |
| Melperone | 40.2 | 5.8 | 95 | 3.8 |
| Melperone | 136.9 | 5.2 | 319 | 3.8 |
| Norclozapine | 24.6 | 6.6 | 59 | 4.4 |
| Norquetiapine | 80.7 | 7.6 | 198 | 4.5 |
| Olanzapine | 120.4 | 7.0 | 287 | 4.6 |
| Paliperidone | 117.2 | 7.6 | 268 | 4.8 |
| Perazine | 68.7 | 7.8 | 164 | 5.3 |
| Pipamperone | 194.8 | 9.4 | 449 | 5.8 |
| Promethazine | 29.2 | 6.7 | 66 | 6.2 |
| Prothipendyl | 207.5 | 4.3 | 505 | 6.2 |
| Quetiapine | 35.6 | 6.8 | 80 | 6.6 |
| Risperidone | 34.8 | 7.5 | 80 | 6.8 |
| Sertindole | 13.6 | 6.9 | 32 | 5.3 |
| Sulpiride | 2.2 | 6.7 | 5 | 4.1 |
| Thioridazine | 29.7 | 8.7 | 72 | 9.3 |
| Ziprasidone | 68.7 | 8.7 | 160 | 8.7 |
| Zotepine | 97.9 | 5.9 | 230 | 7.6 |
| Zuclopenthixole | 2.2 | 3.9 | 5 | 6.0 |

## Conclusions

A robust, reliable, and sensitive liquid chromatography-tandem mass spectrometry method for clinical research for the quantification of 28 different neuroleptics in human plasma or serum was implemented. The ClinMass TDM Platform with the ClinMass Add-On Set for Neuroleptics from RECIPE was used. The method was analytically validated on a Vanquish Flex system connected to a TSQ Quantis triple quadrupole mass spectrometer. The method offers a quick and simple offline sample precipitation with concomitant internal standard addition. The described method meets research laboratory requirements in terms of sensitivity, linearity of response, accuracy, and precision.

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