**ATTACHMENT A-2**

# MODELS FOR ESTIMATION OF GLOBAL FREQUENCIES OF MEDICAL EXPOSURE

UNSCEAR 2020/2021 Report, Annex A, Evaluation of medical exposure to ionizing radiation

## Contents

This electronic attachment summarises the results for three continuous models (Power law in absolute space, Power law in log space, and Negative binomial regression) considered in deriving estimates of examination frequencies for the global assessment in the seven general modality categories of medical exposure. More details on the predictions of the modelling are presented in electronic attachment A-3.

## Acknowledgements

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## Notes



This publication has not been formally edited.

# CONTENTS

# I. INTRODUCTION

1. This electronic attachment summarizes the results for three continuous models (Power law in absolute space, Power law in log space, and Negative binomial regression) considered in deriving estimates of examination frequencies for the Committee’s global assessment. Results are shown for conventional radiology (excluding dental) examinations in tables A-2.1–A-2.4; for dental radiology examinations in tables A-2.5–A-2.8; for computed tomography (CT) examinations in tables A-2.9–A-2.12; for interventional radiology procedures in tables A-2.13–A-2.16; for diagnostic nuclear medicine procedures in tables A-2.17–A-2.20; for radionuclide therapy treatments in tables A-2.21–A-2.24; and for radiation therapy treatments in tables A-2.25–A-2.28. The mean squared error for all models is calculated by comparison to the absolute values for the assessment data. The model selected for the global assessment is the power-law fit in absolute data space. Although the mean squared error for this model is not always the lowest of the models tested, this model has been chosen because of its simplicity, involving only a single predictor variable (physician density), its satisfactory predictive power, and the availability of the data for the predictor variable. Aside from these considerations, the predictions from all models are quite similar.

# II. CONVENTIONAL RADIOLOGY (EXCLUDING DENTAL)

2. For conventional radiology (excluding dental), survey data from 43 countries were included in the evaluation. After inclusion of mainly European data [E1] and few other sources, data from 65 countries, covering 48% of the total world population, contributed to the assessment. The model estimates range from 2.1 billion to 2.6 billion examinations per annum (table A-2.1). With the selected power law model fitted in the absolute data space, the total number of conventional radiology (excluding dental) examinations across the world is assessed at 2.6 billion per annum.

**Table A-2.1. Results for three continuous models tested for estimation of examination frequencies of conventional radiology (excluding dental)**

| *Model* | *Power law (absolute space)*[a] | *Power law (log space)* | *Negative binomial regression (5 parameters)* |
|---|---|---|---|
| Mean squared error[b] | 111 000 | 128 000 | 100 000 |
| Conventional radiology (excluding dental) examinations in assessment data (millions) | 1 587 | 1 587 | 1 587 |
| Additional conventional radiology examinations from model (millions) | 1 039 | 551 | 843 |
| Total conventional radiology examinations (millions) | 2 626 | 2 138 | 2 430 |
| Countries with no prediction due to missing data | 1 | 1 | 14 |
| Proportion of total population included | 99.8% | 99.8% | 99.3% |

[a] Selected model for UNSCEAR global assessment.

[b] Mean squared error for all models is calculated by comparison to the absolute value.

3. Tables A-2.2–A-2.4 show breakdowns of the projected number of examinations and the average examination frequencies by health-care level and income level for conventional radiology (excluding dental) for the three different continuous models.

**Table A-2.2. Results of continuous modelling for the power law model[a] (absolute space) for examination frequencies of conventional radiology (excluding dental) categorized by health-care and income levels**

| | *Radiography examinations in assessment data (millions)* | *Additional radiography examinations from modelled data (millions)* | *Total radiography examinations (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 1 568 | 285 | 1 853 | 474 |
| II | 0.28 | 645 | 645 | 286 |
| III | 19 | 75 | 94 | 151 |
| IV | 0.038 | 34 | 34 | 65 |
| Income level | | | | |
| High | 961 | 22 | 983 | 855 |
| Upper middle | 539 | 225 | 764 | 292 |
| Lower middle | 87 | 714 | 801 | 278 |
| Low | 0.3 | 78 | 78 | 118 |
| All | 1 587 | 1 039 | 2 626 | 359 |

[a] Selected model for UNSCEAR global assessment.

**Table A-2.3. Results of continuous modelling for the power law model (log space) for examination frequencies of conventional radiology (excluding dental) categorized by health-care and income levels**

| | *Radiography examinations in assessment data (millions)* | *Additional radiography examinations from modelled data (millions)* | *Total radiography examinations (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 1 568 | 216 | 1 784 | 456 |
| II | 0.28 | 307 | 307 | 136 |
| III | 19 | 22 | 41 | 66 |
| IV | 0.038 | 6.2 | 6.2 | 12 |
| Income level | | | | |
| High | 961 | 17 | 978 | 851 |
| Upper middle | 539 | 159 | 698 | 267 |
| Lower middle | 87 | 342 | 429 | 149 |
| Low | 0.3 | 33 | 33 | 51 |
| All | 1 587 | 551 | 2 138 | 292 |

**Table A-2.4. Results of continuous modelling for the negative binomial regression (5 parameters) for examination frequencies of conventional radiology (excluding dental) categorized by health-care and income levels**

| *Category* | *Radiography examinations in assessment data (millions)* | *Additional radiography examinations from modelled data (millions)* | *Total radiography examinations (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 1 568 | 156 | 1 724 | 441 |
| II | 0.28 | 536 | 536 | 238 |
| III | 19 | 107 | 126 | 203 |
| IV | 0.038 | 44 | 44 | 84 |
| Income level | | | | |
| High | 961 | 21 | 982 | 854 |
| Upper middle | 539 | 170 | 709 | 271 |
| Lower middle | 87 | 604 | 691 | 240 |
| Low | 0.3 | 48 | 48 | 72 |
| All | 1 587 | 843 | 2 430 | 332 |

## III. DENTAL RADIOLOGY

4. For dental radiology, UNSCEAR Global Survey data from 36 countries were included in the assessment. After inclusion of European data [E1] and few other sources, data from 49 countries, covering 41% of the total world population contributed to the assessment. Table A-2.5 shows the results for the three continuous models ranging from 1.0 billion to 1.1 billion examinations per annum. The negative binomial regression model is clearly a better fit to the assessment data. The spread of results is quite narrow, however, and the choice of model has only a slight impact on the overall result. The selected power law model fitted in the absolute data space gives a worldwide total estimate of dental radiology examinations of 1.1 billion per annum.

**Table A-2.5. Results for three continuous models tested for estimation of examination frequencies for dental radiology**

| *Model* | *Power law (absolute space)[a]* | *Power law (log space)* | *Negative binomial regression (5 parameters)* |
|---|---|---|---|
| Mean squared error[b] | 50 000 | 59 000 | 33 000 |
| Dental radiology examinations in assessment data (millions) | 809 | 809 | 809 |
| Additional dental radiology examinations from model (millions) | 292 | 246 | 192 |
| Total dental radiology examinations (millions) | 1 101 | 1 055 | 1 001 |
| Countries with no prediction due to missing data | 1 | 1 | 15 |
| Proportion of total population included | 99.8% | 99.8% | 99.2% |

[a] Selected model for UNSCEAR global assessment.

[b] Mean squared error for all models is calculated by comparison to the absolute value.

5. Tables A-2.6–A-2.8 show breakdowns of the projected number of examinations and the average examination frequencies by health-care level and income level for dental radiology for the three different models.

**Table A-2.6. Results of continuous modelling for the power law model[a] (absolute space) for examination frequencies of dental radiology categorized by health-care and income levels**

| *Category* | *Dental radiology examinations in assessment data (millions)* | *Additional dental radiology examinations from modelled data (millions)* | *Total dental radiology examinations (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 809 | 173 | 982 | 251 |
| II | 0.068 | 111 | 111 | 49 |
| III | 0 | 6.9 | 6.9 | 11 |
| IV | 0 | 1.1 | 1.1 | 2 |
| Income level | | | | |
| High | 628 | 16 | 644 | 561 |
| Upper middle | 164 | 125 | 289 | 110 |
| Lower middle | 17 | 137 | 154 | 53 |
| Low | 0 | 14 | 14 | 21 |
| All | 809 | 292 | 1 101 | 151 |

[a] Selected model for UNSCEAR global assessment.

**Table A-2.7. Results of continuous modelling for the power law model (log space) for examination frequencies of dental radiology categorized by health-care and income levels**

| *Category* | *Dental radiology examinations in assessment data (millions)* | *Additional dental radiology examinations from modelled data (millions)* | *Total dental radiology examinations (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 809 | 134 | 943 | 241 |
| II | 0.068 | 103 | 103 | 46 |
| III | 0 | 7.6 | 7.6 | 12 |
| IV | 0 | 1.4 | 1.4 | 2.7 |
| Income level | | | | |
| High | 628 | 12 | 640 | 557 |
| Upper middle | 164 | 97 | 261 | 100 |
| Lower middle | 17 | 125 | 142 | 49 |
| Low | 0 | 12 | 12 | 18 |
| All | 809 | 246 | 1 055 | 144 |

**Table A-2.8. Results of continuous modelling for the negative binomial regression (5 parameters) for examination frequencies of dental radiology categorized by health-care and income levels**

| *Category* | *Dental radiology examinations in assessment data (millions)* | *Additional dental radiology examinations from modelled data (millions)* | *Total dental radiology examinations (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 809 | 93 | 902 | 231 |
| II | 0.068 | 75 | 75 | 33 |
| III | 0 | 16 | 16 | 26 |
| IV | 0 | 8 | 8 | 16 |
| Income level | | | | |
| High | 628 | 14 | 642 | 559 |
| Upper middle | 164 | 84 | 248 | 95 |
| Lower middle | 17 | 85 | 102 | 35 |
| Low | 0 | 9 | 9 | 14 |
| All | 809 | 192 | 1 001 | 137 |

## IV. COMPUTED TOMOGRAPHY

6. UNSCEAR Global Survey data for computed tomography were received from 43 countries. Additional data on computed tomography examination frequencies were obtained from European data [E1] and few other sources such as the Organization for Economic Cooperation and Development. Further data for health-care level III and IV countries were taken from previous UNSCEAR reports [U1, U2]. The assessment included data from 69 countries, covering 48% of the total world population. Summary results for the three continuous models are shown in table A-2.9. The estimated results range from 314 million to 403 million examinations per annum. The selected power law model fitted in the absolute data space gives a total estimate for computed tomography examinations worldwide of 400 million per annum.

**Table A-2.9. Results for three continuous models tested for estimation of examination frequencies for computed tomography**

| *Model* | *Power law (absolute space)[a]* | *Power law (log space)* | *Negative binomial regression (2 parameters)* |
|---|---|---|---|
| Mean squared error[b] | 2 940 | 3 090 | 3 180 |
| Computed tomography examinations in assessment data (millions) | 278 | 278 | 278 |
| Additional computed tomography examinations from model (millions) | 125 | 87 | 36 |
| Total computed tomography examinations (millions) | 403 | 365 | 314 |
| Countries with no prediction due to missing data | 1 | 1 | 9 |
| Proportion of total population included | 99.8% | 99.8% | 99.4% |

[a] Selected model for UNSCEAR global assessment.

[b] Mean squared error for all models is calculated by comparison to the absolute value.

7. Tables A-2.10–A-2.12 show breakdowns of the projected number of examinations and the average examination frequencies by health-care level and income level for computed tomography for the three different models.

**Table A-2.10. Results of continuous modelling for the power law model[a] (absolute space) for examination frequencies of computed tomography categorized by health-care and income levels**

| *Category* | *CT examinations in assessment data (millions)* | *CT examinations from modelled data (millions)* | *Total CT examinations (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 278 | 46 | 324 | 83 |
| II | 0 | 70 | 70 | 31 |
| III | 0.52 | 6.5 | 7.0 | 11 |
| IV | 0.062 | 1.88 | 1.9 | 3.7 |
| Income level | | | | |
| High | 181 | 1.3 | 183 | 159 |
| Upper middle | 92.6 | 38.7 | 131 | 50 |
| Lower middle | 4.4 | 77 | 81 | 28 |
| Low | 0.011 | 7.8 | 7.8 | 12 |
| All | 278 | 125 | 403 | 55 |

[a] Selected model for UNSCEAR global assessment.

**Table A-2.11. Results of continuous modelling for the power law model (log space) for examination frequencies of computed tomography categorized by health-care and income levels**

| *Category* | *CT examinations in assessment data (millions)* | *CT examinations from modelled data (millions)* | *Total CT examinations (millions)* | *Frequency per 1 000* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 278 | 39 | 317 | 81 |
| II | 0 | 44 | 44 | 20 |
| III | 0.52 | 3.0 | 3.5 | 5.6 |
| IV | 0.062 | 0.63 | 0.69 | 1.3 |
| Income level | | | | |
| High | 181 | 1.2 | 183 | 159 |
| Upper middle | 92.6 | 31.9 | 124 | 48 |
| Lower middle | 4.4 | 48.5 | 53 | 18 |
| Low | 0.011 | 5 | 5 | 7.5 |
| All | 278 | 87 | 365 | 50 |

**Table A-2.12. Results of continuous modelling for the negative binomial regression (2 parameters) for examination frequencies of computed tomography categorized by health-care and income levels**

| *Category* | *CT examinations in assessment data (millions)* | *CT examinations from modelled data (millions)* | *Total CT examinations (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 278 | 17 | 295 | 75 |
| II | 0 | 15 | 15 | 6.6 |
| III | 0.52 | 3.3 | 3.8 | 6.1 |
| IV | 0.062 | 0.4 | 0.46 | 0.9 |
| Income level | | | | |
| High | 181 | 1.5 | 182.8 | 159 |
| Upper middle | 92.6 | 16.8 | 109.4 | 42 |
| Lower middle | 4.4 | 16.7 | 21.1 | 7.3 |
| Low | 0.011 | 0.7 | 0.7 | 1.1 |
| All | 278 | 36 | 314 | 43 |

## V. INTERVENTIONAL RADIOLOGY

8. For interventional radiology, UNSCEAR Global Survey data were received from 39 countries. After inclusion of European data [E1] and data from previous UNSCEAR reports [U1, U2] a total of 57 countries, covering 46% of the total world population, contributed to the assessment. Summary results for the three continuous models are shown in table A-2.13. The estimated results range from 17.5 million to 23.6 million procedures per annum. The selected power law model fitted in the absolute data space gives a total estimate for interventional radiology procedures across the world of 23.6 million per annum.

**Table A-2.13. Results for three continuous models tested for estimation of procedure frequencies for interventional radiology**

| *Model* | *Power law (absolute space)[a]* | *Power law (log space)* | *Negative binomial regression (5 parameters)* |
|---|---|---|---|
| Mean squared error[b] | 45 | 54 | 39 |
| Interventional radiology procedures in assessment data (millions) | 16.5 | 16.5 | 16.5 |
| Additional interventional radiology procedures from model (millions) | 7.1 | 2.3 | 1.0 |
| Total interventional radiology procedures (millions) | 23.6 | 18.8 | 17.5 |
| Countries with no prediction due to missing data | 1 | 1 | 9 |
| Proportion of total population included | 99.8% | 99.8% | 99.4% |

[a] Selected model for UNSCEAR global assessment.

[b] Mean squared error for all models is calculated by comparison to the absolute value.

9. Tables A-2.14–A-2.16 show breakdowns of the projected number of procedures and the average procedure frequencies by health-care level and income level for interventional radiology categorized for the three different models.

**Table A-2.14. Results of continuous modelling for the power law model[a] (absolute space) for frequencies of interventional radiology procedures categorized by health-care and income levels**

| *Category* | *Interventional procedures in assessment data (millions)* | *Interventional procedures from modelled data (millions)* | *Total interventional procedures (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 16.52 | 2.82 | 19.34 | 4.9 |
| II | 0 | 3.92 | 3.92 | 1.7 |
| III | 0.012 | 0.30 | 0.31 | 0.5 |
| IV | 0 | 0.087 | 0.087 | 0.17 |
| Income level | | | | |
| High | 13.45 | 0.44 | 13.89 | 12.1 |
| Upper middle | 3.04 | 1.93 | 4.97 | 1.9 |
| Lower middle | 0.033 | 4.32 | 4.35 | 1.5 |
| Low | 0 | 0.44 | 0.44 | 0.7 |
| All | 16.53 | 7.12 | 23.65 | 3.2 |

[a] Selected model for UNSCEAR global assessment.

**Table A-2.15. Results of continuous modelling for the power law model (log space) for frequencies of interventional radiology procedures categorized by health-care and income levels**

| *Category* | *Interventional procedures in assessment data (millions)* | *Interventional procedures from modelled data (millions)* | *Total interventional procedures (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 16.52 | 1.36 | 17.88 | 4.6 |
| II | 0 | 0.86 | 0.86 | 0.38 |
| III | 0.012 | 0.03 | 0.04 | 0.07 |
| IV | 0 | 0.004 | 0.004 | 0.01 |
| Income level | | | | |
| High | 13.45 | 0.23 | 13.68 | 11.9 |
| Upper middle | 3.04 | 0.87 | 3.91 | 1.5 |
| Lower middle | 0.033 | 1.01 | 1.04 | 0.36 |
| Low | 0 | 0.14 | 0.14 | 0.22 |
| All | 16.53 | 2.26 | 18.79 | 2.6 |

**Table A-2.16. Results of continuous modelling for the negative binomial regression (5 parameters) for frequencies of interventional radiology procedures categorized by health-care and income levels**

| *Category* | *Interventional procedures in assessment data (millions)* | *Interventional procedures from modelled data (millions)* | *Total interventional procedures (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 16.52 | 0.65 | 17.17 | 4.4 |
| II | 0 | 0.29 | 0.29 | 0.13 |
| III | 0.012 | 0.056 | 0.068 | 0.11 |
| IV | 0 | 0.004 | 0.004 | 0.008 |
| Income level | | | | |
| High | 13.45 | 0.33 | 13.78 | 12.0 |
| Upper middle | 3.04 | 0.40 | 3.45 | 1.3 |
| Lower middle | 0.03 | 0.27 | 0.30 | 0.10 |
| Low | 0 | 0.003 | 0.003 | 0.005 |
| All | 16.53 | 1.00 | 17.53 | 2.4 |

## VI. DIAGNOSTIC NUCLEAR MEDICINE

10. The assessment for diagnostic nuclear medicine procedures included UNSCEAR Global Survey data from 46 countries. With the addition of European data [E1] and from previous UNSCEAR reports [U1, U2], data from 68 countries, covering 52% of the total world population, contributed to the assessment. Summary results for the three continuous models are shown in table A-2.17. The estimated results range from 37 million to 40 million procedures per annum. The selected power law model fitted in the absolute data space gives a total estimate for diagnostic nuclear medicine procedures across the world of 40 million per annum.

**Table A-2.17. Results for three continuous models tested for estimation of procedure frequencies for diagnostic nuclear medicine**

| *Model* | *Power law (absolute space)[a]* | *Power law (log space)* | *Negative binomial regression (3 parameters)* |
|---|---|---|---|
| Mean squared error[b] | 104 | 111 | 84 |
| Nuclear medicine procedures in assessment data (millions) | 34.1 | 34.1 | 34.1 |
| Additional nuclear medicine procedures from model (millions) | 5.8 | 4.5 | 3.1 |
| Total nuclear medicine procedures (millions) | 39.9 | 38.6 | 37.2 |
| Countries with no prediction due to missing data | 1 | 1 | 15 |
| Proportion of total population included | 99.8% | 99.8% | 99.3% |

[a] Selected model for UNSCEAR global assessment.

[b] Mean squared error for all models is calculated by comparison to the absolute value.

11. Tables A-2.18–A-2.20 show breakdowns of the projected number of procedures and the average procedure frequencies by health-care level and income level for diagnostic nuclear medicine for the three different models.

**Table A-2.18. Results of continuous modelling for the power law model[a] (absolute space) for frequencies of diagnostic nuclear medicine procedures categorized by health-care and income levels**

| *Category* | *Nuclear medicine procedures in assessment data (millions)* | *Nuclear medicine procedures from modelled data (millions)* | *Total nuclear medicine procedures (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 33.9 | 3.9 | 37.8 | 10 |
| II | 0.26 | 1.82 | 2.1 | 0.9 |
| III | 0.0037 | 0.072 | 0.076 | 0.12 |
| IV | 0.0023 | 0.0067 | 0.009 | 0.02 |
| Income level | | | | |
| High | 28.1 | 0.39 | 28.5 | 25 |
| Upper middle | 5.4 | 2.8 | 8.2 | 3.2 |
| Lower middle | 0.57 | 2.2 | 2.8 | 1.0 |
| Low | 0.0006 | 0.39 | 0.39 | 0.6 |
| All | 34.1 | 5.8 | 39.9 | 5.5 |

[a] Selected model for UNSCEAR global assessment.

**Table A-2.19. Results of continuous modelling for the power law model (log space) for frequencies of diagnostic nuclear medicine procedures categorized by health-care and income levels**

| *Category* | *Nuclear medicine procedures in assessment data (millions)* | *Nuclear medicine procedures from modelled data (millions)* | *Total nuclear medicine procedures (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 33.9 | 2.8 | 36.6 | 9.4 |
| II | 0.26 | 1.61 | 1.876 | 0.83 |
| III | 0.0037 | 0.078 | 0.082 | 0.13 |
| IV | 0.0023 | 0.0087 | 0.011 | 0.02 |
| Income level | | | | |
| High | 28.1 | 0.27 | 28.4 | 25 |
| Upper middle | 5.4 | 2.0 | 7.4 | 2.8 |
| Lower middle | 0.57 | 1.92 | 2.49 | 0.9 |
| Low | 0.0006 | 0.29 | 0.29 | 0.44 |
| All | 34.1 | 4.5 | 38.6 | 5.3 |

**Table A-2.20. Results of continuous modelling for the negative binomial regression (3 parameters) for frequencies of diagnostic nuclear medicine procedures categorized by health-care and income levels**

| *Category* | *Nuclear medicine procedures assessment data (millions)* | *Nuclear medicine procedures modelled data (millions)* | *Total nuclear medicine procedures (millions)* | *Frequency per 1 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 33.9 | 1.7 | 35.6 | 9.1 |
| II | 0.26 | 1.06 | 1.3 | 0.59 |
| III | 0.0037 | 0.26 | 0.26 | 0.42 |
| IV | 0.0023 | 0.037 | 0.039 | 0.07 |
| Income level | | | | |
| High | 28.1 | 0.4 | 28.5 | 25 |
| Upper middle | 5.4 | 1.3 | 6.8 | 2.6 |
| Lower middle | 0.57 | 1.34 | 1.9 | 0.66 |
| Low | 0.0006 | 0.065 | 0.065 | 0.10 |
| All | 34.1 | 3.1 | 37.2 | 5.1 |

## VII. RADIONUCLIDE THERAPY

12. UNSCEAR Global Survey data on radionuclide therapy treatments were received from 41 countries, covering 47% of the global population. Summary results for the three continuous models are shown in table A-2.21. The estimated results range from 1.2 million to 1.5 million treatments per annum. The selected power law model fitted in the absolute data space gives a total estimate for radionuclide therapy treatments across the world of 1.4 million per annum.

**Table A-2.21. Results for three continuous models tested for estimation of treatment frequencies for radionuclide therapy**

| *Model* | *Power law (absolute space)[a]* | *Power law (log space)* | *Negative binomial regression (1 parameter)* |
|---|---|---|---|
| Mean squared error[b] | 200 | 228 | 252 |
| Radionuclide therapy treatments in assessment data (millions) | 0.936 | 0.936 | 0.936 |
| Additional radionuclide therapy treatments from model (millions) | 0.496 | 0.305 | 0.539 |
| Total radionuclide therapy treatments (millions) | 1.432 | 1.241 | 1.475 |
| Countries with no prediction due to missing data | 1 | 1 | 1 |
| Proportion of total population included | 99.8% | 99.8% | 99.8% |

[a] Selected model for UNSCEAR global assessment.
[b] Mean squared error for all models is calculated by comparison to the absolute value.

13. Tables A-2.22–A-2.24 show breakdowns of the projected number of treatments and the average treatment frequencies (per 100,000 population) by health-care level and income level for radionuclide therapy for the three different models.

**Table A-2.22. Results of continuous modelling for the power law model[a] (absolute space) for frequencies of radionuclide therapy treatments categorized by health-care and income levels**

| *Category* | *Radionuclide treatments in assessment data (millions)* | *Radionuclide treatments from modelled data (millions)* | *Estimated total number of radionuclide treatments (millions)* | *Frequency per 100 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 0.874 | 0.207 | 1.081 | 28 |
| II | 0.060 | 0.227 | 0.287 | 13 |
| III | 0.0016 | 0.042 | 0.044 | 7 |
| IV | 0 | 0.020 | 0.020 | 4 |
| Income level | | | | |
| High | 0.268 | 0.073 | 0.341 | 30 |
| Upper middle | 0.619 | 0.110 | 0.729 | 28 |
| Lower middle | 0.049 | 0.274 | 0.323 | 11 |
| Low | 0 | 0.039 | 0.039 | 6 |
| All | 0.936 | 0.496 | 1.432 | 20 |

[a] Selected model for UNSCEAR global assessment.

**Table A-2.23. Results of continuous modelling for the power law model (log space) for frequencies of radionuclide therapy treatments categorized by health-care and income levels**

| *Category* | *Radionuclide treatments in assessment data (millions)* | *Radionuclide treatments from modelled data (millions)* | *Estimated total number of radionuclide treatments (millions)* | *Frequency per 100 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 0.874 | 0.149 | 1.023 | 26.2 |
| II | 0.060 | 0.130 | 0.191 | 8.4 |
| III | 0.0016 | 0.019 | 0.020 | 3.3 |
| IV | 0 | 0.007 | 0.007 | 1.3 |
| Income level | | | | |
| High | 0.268 | 0.055 | 0.323 | 28.1 |
| Upper middle | 0.619 | 0.076 | 0.695 | 26.5 |
| Lower middle | 0.049 | 0.155 | 0.204 | 7.1 |
| Low | 0 | 0.019 | 0.019 | 2.9 |
| All | 0.936 | 0.305 | 1.241 | 17.0 |

**Table A-2.24. Results of continuous modelling for the negative binomial regression (1 parameter) for frequencies of radionuclide therapy treatments categorized by health-care and income levels**

| *Category* | *Radionuclide treatments in assessment data (millions)* | *Radionuclide treatments from modelled data (millions)* | *Estimated total number of radionuclide treatments (millions)* | *Frequency per 100 000 population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 0.874 | 0.209 | 1.083 | 28 |
| II | 0.060 | 0.218 | 0.279 | 12 |
| III | 0.0016 | 0.060 | 0.062 | 10 |
| IV | 0 | 0.050 | 0.050 | 9.7 |
| Income level | | | | |
| High | 0.268 | 0.078 | 0.346 | 30 |
| Upper middle | 0.619 | 0.109 | 0.728 | 28 |
| Lower middle | 0.049 | 0.281 | 0.330 | 11 |
| Low | 0 | 0.070 | 0.070 | 11 |
| All | 0.936 | 0.539 | 1.475 | 20 |

## VIII. RADIATION THERAPY

14. The assessment for radiation therapy treatment courses included UNSCEAR Global Survey data from 44 countries, covering 66% of the total world population. Summary results for the three continuous models are shown in table A-2.25. The estimates range from 5.5 million to 6.2 million treatment courses per annum. The selected power law model fitted in the absolute data space gives a total estimate for the number of radiation therapy treatment courses across the world of 6.2 million per annum.

**Table A-2.25. Results of three continuous models tested for estimation of frequencies for radiation therapy treatment courses**

| *Model* | *Power law (absolute space)*[a] | *Power law (log space)* | *Negative binomial regression (4 parameters)* |
|---|---|---|---|
| Mean squared error[b] | 585 000 | 697 000 | 622 000 |
| Radiation therapy treatment courses in assessment data (millions) | 4.7 | 4.7 | 4.7 |
| Additional radiation therapy treatment courses from model (millions) | 1.5 | 1.1 | 0.8 |
| Total radiation therapy treatment courses (millions) | 6.2 | 5.8 | 5.5 |
| Countries with no prediction due to missing data | 1 | 1 | 57 |
| Proportion of total population included | 99.8% | 99.8% | 95.7% |

[a] Selected model for UNSCEAR global assessment.

[b] Mean squared error for all models is calculated by comparison to the absolute value.

15. Tables A-2.26–A-2.28 show breakdowns of the projected number of treatments and the average treatment frequencies (per million population) by health-care level and income level for radiation therapy treatment courses for the three different models.

**Table A-2.26. Results of continuous modelling for the power law model[a] (absolute space) for frequencies of radiation therapy treatment courses categorized by health-care and income levels**

| *Category* | *Radiation therapy treatment courses in assessment data (millions)* | *Radiation therapy treatment courses from modelled data (millions)* | *Estimated total number of radiation therapy treatment courses (millions)* | *Frequency per million population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 4.50 | 1.29 | 5.79 | 1 480 |
| II | 0.225 | 0.154 | 0.379 | 168 |
| III | 0.0036 | 0.050 | 0.053 | 85 |
| IV | 0 | 0.010 | 0.010 | 19 |
| Income level | | | | |
| High | 2.71 | 0.30 | 3.01 | 2 620 |
| Upper middle | 1.82 | 0.80 | 2.63 | 1 000 |
| Lower middle | 0.19 | 0.30 | 0.50 | 172 |
| Low | 0.0002 | 0.10 | 0.10 | 148 |
| All | 4.73 | 1.50 | 6.23 | 853 |

[a] Selected model for UNSCEAR global assessment.

**Table A-2.27. Results of continuous modelling for the power law model (log space) for frequencies of radiation therapy treatment courses categorized by health-care and income levels**

| *Category* | *Radiation therapy treatment courses in assessment data (millions)* | *Radiation therapy treatment courses from modelled data (millions)* | *Estimated total number of radiation therapy treatment courses (millions)* | *Frequency per million population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 4.50 | 0.98 | 5.48 | 1 402 |
| II | 0.225 | 0.048 | 0.273 | 121 |
| III | 0.0036 | 0.0077 | 0.011 | 18 |
| IV | 0 | 0.0008 | 0.0008 | 1 |
| Income level | | | | |
| High | 2.71 | 0.25 | 2.96 | 2 578 |
| Upper middle | 1.82 | 0.60 | 2.42 | 925 |
| Lower middle | 0.19 | 0.13 | 0.32 | 112 |
| Low | 0.0002 | 0.056 | 0.056 | 84 |
| All | 4.73 | 1.03 | 5.76 | 788 |

**Table A-2.28. Results of continuous modelling for the negative binomial regression (4 parameters) for frequencies of radiation therapy treatment courses categorized by health-care and income levels**

| *Category* | *Radiation therapy treatment courses in assessment data (millions)* | *Radiation therapy treatment courses from modelled data (millions)* | *Estimated total number of radiation therapy treatment courses (millions)* | *Frequency per million population* |
|---|---|---|---|---|
| Health-care level | | | | |
| I | 4.50 | 0.62 | 5.12 | 1 310 |
| II | 0.225 | 0.075 | 0.30 | 133 |
| III | 0.0036 | 0.069 | 0.073 | 118 |
| IV | 0 | 0.017 | 0.017 | 32 |
| Income level | | | | |
| High | 2.71 | 0.30 | 3.01 | 2 617 |
| Upper middle | 1.82 | 0.31 | 2.13 | 814 |
| Lower middle | 0.19 | 0.16 | 0.35 | 122 |
| Low | 0.0002 | 0.019 | 0.019 | 29 |
| All | 4.73 | 0.78 | 5.51 | 754 |

# IX. CONCLUSION

16. The modelling results are consistent with the extrapolation results discussed in appendix A of the annex. This consistency supports the overall total adopted from the modelling. In some cases, e.g., for dental radiology and for computed tomography, the consistency of the categorical extrapolations with the modelling results is dependent on assumptions made in the absence of data. This demonstrates the advantages of the modelling approach over extrapolation by categories when there are no or only few data for some categories. The modelling results for health-care level IV and for low-income countries are notably higher than the extrapolation results, suggesting that there may be some over-estimation. However, the extrapolation results at these levels are dependent on data from only one or two countries and, thus, must be considered very unreliable. In any event, the assessed numbers at these levels are a very minor component of the overall analysis.

17. In summary, the selected continuous models for examination frequencies in the seven general modality categories are based on power-law fits in the absolute data space with physician density as the only predictor variable. The total numbers of examinations reported in the present assessment were derived by combining the data submitted to the UNSCEAR Global Survey with the predictions of the selected model for countries that did not provide data to the survey. Detailed results of the predictions from the modelling are presented in electronic attachment A-3.

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