MANC-RISK-SCREEN Version 1: Parameters, Sources, and Assumptions

Table 1: Clinical parameters in deterministic model

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| --- | --- | --- | --- |
| **Parameter** | **Value** | **Updated or added since Gray model?** | **Sources and Assumptions** |
| Probability of attending a screening appointment | 62.5% for the first screen  88.7% if one previous screen attended  20.8% if first screen not attended | Yes | https://digital.nhs.uk/data-and-information/publications/statistical/breast-screening-programme/england---2023-24/mainreport2324#section-4-uptake-of-invitations |
| Uptake for prediction of risk of breast cancer | 100% in base case  60% in sensitivity analysis | Yes | Expert opinion |
| Uptake for receipt of risk information | 100% in base case  95% in sensitivity analysis | Yes | Expert opinion |
| Proportion of women who change screening intervals based on risk information | 100% in base case  80% in base case | Yes | Expert opinion |
| Age of death due to all-cause mortality | ~weibull(9.38,89.35) | Yes | Office for National Statistics (2)  Using the probability of dying at a given age, a small Markov model was created for a with a starting age of 50. This Markov model contained the states alive and dead and recorded the number of individuals expected to die at each age. From this, a simulated data set was created containing the age of death for each individual in the cohort. Using the fitdistrplus package in R, a Weibull distribution was fit to this data. |
| Survival for stage 1 breast cancer | exp(-5.462) | Yes | Office for National Statistics 2019 (3)  Exponential survival curve fitted for median survival for women with stage 1 cancer at 5 years post-diagnosis. A previous version of this model had used Nottingham Prognostic Indicator grade rather than stage but found an exponential curve to be the best fit of multiple models selected. As such the same model was applied to data related to cancer stage |
| Survival for stage 2 breast cancer | exp(-4.023) | Yes | Office for National Statistics 2019 (3)  Exponential survival curve fitted for median survival for women with stage 2 cancer at 5 years post-diagnosis. A previous version of this model had used Nottingham Prognostic Indicator grade rather than stage but found an exponential curve to be the best fit of multiple models selected. As such the same model was applied to data related to cancer stage |
| Survival for stage 3 breast cancer | exp(-2.465) | Yes | Office for National Statistics 2019 (3)  Exponential survival curve fitted for median survival for women with stage 3 cancer at 5 years post-diagnosis. A previous version of this model had used Nottingham Prognostic Indicator grade rather than stage but found an exponential curve to be the best fit of multiple models selected. As such the same model was applied to data related to cancer stage |
| Survival for stage 4 breast cancer for women aged up to 54 | exp(-1.787) | Yes | Office for National Statistics 2019 (3)  Exponential survival curve fitted for median survival for women aged under 54 with stage 4 cancer at 5 years post-diagnosis. A previous version of this model had used Nottingham Prognostic Indicator grade rather than stage but found an exponential curve to be the best fit of multiple models selected. As such the same model was applied to data related to cancer stage |
| Survival for stage 4 breast cancer for women aged 55 to 74 | exp(-1.388) | Yes | Office for National Statistics 2019 (3)  Exponential survival curve fitted for median survival for women aged 55 to 74 with stage 4 cancer at 5 years post-diagnosis. As this age group covered two age bands in the underlying data, a weighted average of the median 5-year survival was calculated. A previous version of this model had used Nottingham Prognostic Indicator grade rather than stage but found an exponential curve to be the best fit of multiple models selected. As such the same model was applied to data related to cancer stage |
| Survival for stage 4 breast cancer for women aged over 75 | exp(-1.011) | Yes | Office for National Statistics 2019 (3)  Exponential survival curve fitted for median survival for women aged over 75 with stage 4 cancer at 5 years post-diagnosis. A previous version of this model had used Nottingham Prognostic Indicator grade rather than stage but found an exponential curve to be the best fit of multiple models selected. As such the same model was applied to data related to cancer stage |
| Breast cancer incidence by age | See “Incidence\_mortality\_ONS2” input csv | Yes | Cancer Research UK 2022 (4) |
| 10 year risk of breast cancer estimated using the Tyrer-Cuzick version 8 and Volpara breast density group | See “synthetic\_risk\_data.csv” input | Yes | Observations of breast density (using Volpara TruDensity), 10 year breast cancer risk (using Tyrer-Cuzick version 8 and Volpara TruDensity), and lifetime risk (using Tyrer-Cuzick version 8 and Volpara TruDensity) for 15,613 women were shared securely by the BC-PREDICT research team. In order to allow this input data to be shared outside the research team, a synthetic data set was created using the synthpop package in R. This approach resulted in a data set with 15,613 synthetically generated observations of breast density, 10 year risk, and lifetime risk. The approach also preserves the structure of the underlying data including correlations. |
| Lifetime risk of breast cancer estimated using the Tyrer-Cuzick version 8 and Volpara breast density group | See “synthetic\_risk\_data.csv” input | Yes | Observations of breast density (using Volpara TruDensity), 10 year breast cancer risk (using Tyrer-Cuzick version 8 and Volpara TruDensity), and lifetime risk (using Tyrer-Cuzick version 8 and Volpara TruDensity) for 15,613 women were shared securely by the BC-PREDICT research team. In order to allow this input data to be shared outside the research team, a synthetic data set was created using the synthpop package in R. This approach resulted in a data set with 15,613 synthetically generated observations of breast density, 10 year risk, and lifetime risk. The approach also preserves the structure of the underlying data including correlations. |
| Volpara breast density estimate | See “synthetic\_risk\_data.csv” input | Yes | Observations of breast density (using Volpara TruDensity), 10 year breast cancer risk (using Tyrer-Cuzick version 8 and Volpara TruDensity), and lifetime risk (using Tyrer-Cuzick version 8 and Volpara TruDensity) for 15,613 women were shared securely by the BC-PREDICT research team. In order to allow this input data to be shared outside the research team, a synthetic data set was created using the synthpop package in R. This approach resulted in a data set with 15,613 synthetically generated observations of breast density, 10 year risk, and lifetime risk. The approach also preserves the structure of the underlying data including correlations. |
| Probability that a cancer is metastatic given the age of the woman | 25=4.62%  35=8.67%  45=10.98%  55=12.71%  65=14.25%  75=15.98%  85=17.30% | No | Age nearest to woman’s current age at diagnosis of cancer used |
| Probability of cancer being diagnosed as stage I, II, or III given size of tumour | See stage\_by\_size\_mat in R script | Yes | Kollias et al. (1998), Wen et al. (2015), Cheng et al. (1997) (5–7)  The supplementary data provided in Wen et al. provided observations of cancer size, number of lymph node involvements, and other variables for 1,661 women. Given that none of the patients had metastatic cancer, it was possible to determine the stage of cancer for each woman using the size of the tumour and number of lymph nodes involved. This data was used to determine the probability that cancers of different sizes would be of different stages. However, the data set contained few observation for women with very small tumours. As such, data from Kollias et al. was combined with that included in Wen et al. to provide a better representation of the distribution of stages in very small cancers. As Kollias et al. only included whether lymph nodes were involved or not and did not state the number of nodes, it was assumed that half of patients with node involvement had one node and half had more than one node. The distributions of stages across cancer size was compared between the studies and aside from the smallest cancers the studies showed close agreement.  The likelihood a cancer of a given size was a DCIS was calculated using the distribution of DCIS tumour sizes from Cheng et al (1997) and the proportion of cancers that were DCIS (21.1%) from NHS England screening statistics. The stage\_by\_size\_mat was re-calculated such that a cancer of a given size had a probability of being of stage I-III or a DCIS. |
| Mammographic sensitivity by Volpara Density Group (VDG) | VDG1=75.0%  VDG2=73.5%%  VDG3=59.8%  VDG4=51.3%  Average=66.6% | Yes | Payne et al. (2025) (8) |
| Detection rate of mammography in high density screens | 4.2 per 1,000 screens | No | Tice et al. (2013) (9) |
| Incremental detection rate of magnetic resonance imaging mammography in high density screens after negative mammography | 5 per 1,000 screens | No | Vreeman et al. (personal communication, 2015) see Gray et al. (2017) (10) |
| Incremental detection rate of ultrasound mammography in high density screens after negative mammography | 3 per 1,000 screens | No | Tice et al (2013) (9) |
| Recall (false-positive) rate for screening | 3.1% | Yes | https://digital.nhs.uk/data-and-information/publications/statistical/breast-screening-programme/england---2020-21/qualitystatement3  https://digital.nhs.uk/data-and-information/publications/statistical/breast-screening-programme/england---2023-24/mainreport2324#section-5-outcome-of-screening |
| Biopsy rate for recalls | 50.6% | Yes | NHS Digital Screening and Immunisations Team (2021) (1) |
| Growth Model Parameters | | | |
| Mean tumour doublings at clinical detection | 6.5 | No | Weedon-Fekjær et al. (2008) (12) |
| Standard deviation of tumour doublings at clinical detection | 0.535 | No | Weedon-Fekjær et al. (2008) (12) |
| Log normal mean of tumour growth rate | 1.07 | No | Weedon-Fekjær et al. (2008) (12) |
| Log normal standard deviation of tumour growth rate | 1.31 | No | Weedon-Fekjær et al. (2008) (12) |
| Maximum tumour size (mm) | 128 | No | Weedon-Fekjær et al. (2008) (12) |
| Starting tumour size (mm) | 0.25 | No | Weedon-Fekjær et al. (2008) (12) |
|  |  |  |  |

Table 2: Costs used in deterministic model

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Value** | **Updated or added since Gray model?** | **Sources and Assumptions** |
| Cost of risk stratification | £8.45 | Yes | Ongoing microcosting study  See model parameter update documents |
| Cost of mammography screen | £60.56 | Yes | Pragmatic microcosting  See model parameter update document |
| Cost of follow up | £106.16 | Yes | Inflated from value in Gray et al. (2017) (10) |
| Cost of biopsy | £290 | Yes | NHS England (2022) (13) |
| Cost of ultrasound screening | £52 | Yes | NHS England (2022) (13) |
| Cost of MRI screening | £114 | Yes | NHS England (2022) (13) |
| Cost of treating breast cancer by stage, age, and time lived with cancer | See tibble in R script | Yes | Laudicella et al. (2015) (14)  Laudicella provide estimates of the costs of treating breast cancer in the UK from the two years preceding to eight years following diagnosis. Costs are broken down by stage of cancer (early versus late) and age (under or over 65). These costs were included as an input table in the model. They were then inflated to 2022 levels. An exponential regression was then fit to the data to predict the total cost of treating an individual’s cancer given the length of time they had the cancer, their age of diagnosis, and the stage of their cancer. If a patient was alive for over 8 years following diagnosis the cost of treating their cancer was assumed to be £0 in any subsequent years. |
| Cost of treating a ductal carcinoma in-situ | £9,480.15 | Yes | Inflated from value in Gray et al. (2017) (10) |

Table 3: Utility values used in the deterministic model

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Value** | **Updated or added since Gray model?** | **Sources and Assumptions** |
| Age-related utility values for healthy individuals | 30=0.938  35=0.915  40=0.907  45=0.882  50=0.864  55=0.834  60=0.822  65=0.807  70=0.804  75=0.779  80=0.753  85=0.699  90=0.650  95=0.650  100=0.650 | No | Ara and Brazier (2011) (15) |
| Utility early breast cancer in the first year | 0.82 | Yes | Naik et al. (2017) (16)  Potential utility values were identified from two systematic reviews of utility values in breast cancer (17,18). From the studies included in these reviews, three studies which estimated utility values covering local and metastatic cancer, conducted in high income countries, and using either EQ-5D and relevant value sets or the time-trade off approach were identified. A focus group was then held with three women who had recovered from breast cancer to decide which of the three sets of utility values they felt best represented the experience of women in the UK.  The values in the chosen study did not change between the first and subsequent years and it was for this reason that the women in the focus group chose the set. However, the ability to choose different values for subsequent years was retained in the model in case future research suggests this is useful for inclusion. |
| Utility early breast cancer in subsequent years | 0.82 | Yes | Naik et al. (2017) (16)  Potential utility values were identified from two systematic reviews of utility values in breast cancer (17,18). From the studies included in these reviews, three studies which estimated utility values covering local and metastatic cancer, conducted in high income countries, and using either EQ-5D and relevant value sets or the time-trade off approach were identified. A focus group was then held with three women who had recovered from breast cancer to decide which of the three sets of utility values they felt best represented the experience of women in the UK.  The values in the chosen study did not change between the first and subsequent years and it was for this reason that the women in the focus group chose the set. However, the ability to choose different values for subsequent years was retained in the model in case future research suggests this is useful for inclusion. |
| Advanced breast cancer in the first year | 0.75 |  | Naik et al. (2017) (16)  Potential utility values were identified from two systematic reviews of utility values in breast cancer (17,18). From the studies included in these reviews, three studies which estimated utility values covering local and metastatic cancer, conducted in high income countries, and using either EQ-5D and relevant value sets or the time-trade off approach were identified. A focus group was then held with three women who had recovered from breast cancer to decide which of the three sets of utility values they felt best represented the experience of women in the UK.  The values in the chosen study did not change between the first and subsequent years and it was for this reason that the women in the focus group chose the set. However, the ability to choose different values for subsequent years was retained in the model in case future research suggests this is useful for inclusion. |
| Advanced breast cancer in subsequent years | 0.75 | Yes | Naik et al. (2017) (16)  Potential utility values were identified from two systematic reviews of utility values in breast cancer (17,18). From the studies included in these reviews, three studies which estimated utility values covering local and metastatic cancer, conducted in high income countries, and using either EQ-5D and relevant value sets or the time-trade off approach were identified. A focus group was then held with three women who had recovered from breast cancer to decide which of the three sets of utility values they felt best represented the experience of women in the UK.  The values in the chosen study did not change between the first and subsequent years and it was for this reason that the women in the focus group chose the set. However, the ability to choose different values for subsequent years was retained in the model in case future research suggests this is useful for inclusion. |

Table 4: Input parameters with sampling distributions and hyperparameters used in PSA

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Distribution** | **Hyperparameter 1** | **Hyperparameter 2** | **Updated or added since Gray model?** |
| Mammographic Sensitvity | | Mean | Standard deviation |  |
| Beta 1 | Normal | 1.47 | 0.1 | No |
| Beta 2 | Normal | 6.51 | 0.5 | No |
| VDG modifiers | |  |  |  |
| VDG 1 | Beta | 96 | 16 | Yes |
| VDG 2 | Beta | 298 | 86 | Yes |
| VDG 3 | Beta | 212 | 93 | Yes |
| VDG 4 | Beta | 61 | 39 | Yes |
| Supplemental imaging | |  |  |  |
| US | Beta | 35.89 | 11927 | No |
| MRI | Beta | 99.495 | 19799.5 | No |
|  |  |  |  |  |
| Growth rate distribution | | Mean | Standard deviation |  |
|  | Normal | 1.07 | 0.09 | No |
|  | Normal | 1.31 | 0.11 | No |
|  |  |  |  |  |
| Survival post-BC | | Mean | Correlated draws |  |
| stage I | Multivariate normal (MVN) | -5.46 | See Table 5 | Yes |
| stage II | MVN | -3.82 | See Table 5 | Yes |
| stage III | MVN | -2.72 | See Table 5 | Yes |
| Survival metastatic BC |  | Mean | Correlated draws |  |
| stage IV, age <55 | MVN | -1.79 | See Table 6 | Yes |
| stage IV, age 55-74 | MVN | -1.39 | See Table 6 | Yes |
| stage IV, age >74 | MVN | -1.01 | See Table 6 | Yes |
| Utility weights | | | |  |
| Early | 1-exp(MVN) | -1.71 | See Table 7 | Yes |
| Advanced cancer | 1-exp(MVN) | -1.39 | See Table 7 | Yes |
| Costs |  | Mean | Standard Deviation |  |
| Risk stratification | Log normal | 2.13 | 0.06 | Yes |
| Cost multiplier (independently drawn and applied for each other cost item) | Normal | 0 | 0.102 | Yes |

Table 6: Covariance matrix for survival post-BC

|  |  |  |
| --- | --- | --- |
| 0.08878 |  |  |
| 0.01819 | 0.00373 |  |
| 0.01866 | 0.00384 | 0.00395 |

Table 7: Covariance matrix for metastatic survival

|  |  |  |
| --- | --- | --- |
| 0.01157 |  |  |
| 0.00884 | 0.00705 |  |
| 0.00804 | 0.00613 | 0.00560 |

Table 8: Covariance matrix for utility values

|  |  |
| --- | --- |
| 0.00309 |  |
| 0.00446 | 0.00643 |

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