

Additional file 4

Additional file 4.pdf

Title: Categorization of evaluation metrics to different performance levels for assessing Robustness of MICE procedure

The evaluation metrics used in the study were categorized into different performance levels based on their values. The range of each metric (calculated as the maximum value minus the desirable value) was divided into three equal parts. Metrics falling within each part were then classified into corresponding performance categories: 'high performance', 'medium performance', and 'low performance'.

Root Mean Square Error (RMSE): The RMSE values, ideally close to zero, indicate the accuracy of imputed data. Among the indicators, the highest RMSE values were observed for 90% imputed data of AMR, UMR, IMR, NMR, and SBR, recorded at 72.885, 29.888, 17.796, 11.712, and 7.385 respectively. These RMSE values were divided equally into three intervals for each health indicator to establish performance levels (High, Medium, and Low) as detailed in Table S4.

Mean Absolute Deviation (MAD): The MAD is ideally close to zero. The highest MAD values were recorded for 90% imputed data across the AMR, UMR, IMR, NMR, and SBR indicators, with values of 58.671, 20.224, 13.267, 10.131, and 5.217, respectively. These values were evenly divided into three segments to establish performance levels (High, Medium, and Low), as detailed in Table S4.

BIAS: For BIAS, a value of zero signifies no bias, while positive values indicate overestimation and negative values indicate underestimation of the true value. The highest absolute bias values were observed for 80%, 90%, 60%, 80%, and 60% imputed data across the AMR, UMR, IMR, NMR, and SBR indicators, respectively, recorded as 7.686, 8.249, 3.492, 1.242, and 1.065. These values were equally partitioned into three intervals for each health indicator to delineate performance levels (High, Medium, and Low), as outlined in Table S4.

Proportionate Variance (PV): A PV value closer to one is desirable, indicating minimal deviation from the true data. The highest deviations of PV values from 1 were observed to be 0.998, 0.792, 0.662, 0.982, and 0.791 for 90% imputed data across the AMR, UMR, IMR,

NMR, and SBR indicators, respectively. These values were evenly distributed into three categories to establish performance levels (High, Medium, and Low), as presented in Table S4.

Table S4: Categorization of evaluation metrics to different performance levels

Evaluation metric	Health Indicator	Performance levels		
		High	Medium	Low
RMSE	AMR	$RMSE \leq 24.295$	$24.295 < RMSE \leq 48.59$	$RMSE > 48.59$
	UMR	$RMSE \leq 9.963$	$9.963 < RMSE \leq 19.926$	$RMSE > 19.926$
	IMR	$RMSE \leq 5.932$	$5.932 < RMSE \leq 11.864$	$RMSE > 11.864$
	NMR	$RMSE \leq 3.904$	$3.904 < RMSE \leq 7.808$	$RMSE > 7.808$
	SBR	$RMSE \leq 2.642$	$2.642 < RMSE \leq 5.284$	$RMSE > 5.284$
MAD	AMR	$MAD \leq 19.557$	$19.557 < MAD \leq 39.114$	$MAD > 39.114$
	UMR	$MAD \leq 6.741$	$6.741 < MAD \leq 13.482$	$MAD > 13.482$
	IMR	$MAD \leq 4.422$	$4.422 < MAD \leq 8.844$	$MAD > 8.844$
	NMR	$MAD \leq 3.377$	$3.377 < MAD \leq 6.754$	$MAD > 6.754$
	SBR	$MAD \leq 1.739$	$1.739 < MAD \leq 3.478$	$MAD > 3.478$
BIAS	AMR	$-2.562 \leq BIAS < 0$ (underestimation) $0 < BIAS \leq 2.562$ (overestimation)	$-5.124 \leq BIAS < -2.562$ (underestimation) $2.562 < BIAS \leq 5.124$ (overestimation)	$BIAS < -5.124$ (underestimation) $BIAS > 5.124$ (overestimation)
	UMR	$-2.75 \leq BIAS < 0$ (underestimation) $0 < BIAS \leq 2.75$ (overestimation)	$-5.5 \leq BIAS < -2.75$ (underestimation) $2.75 < BIAS \leq 5.5$ (overestimation)	$BIAS < -5.5$ (underestimation) $BIAS > 5.5$ (overestimation)
	IMR	$-1.164 \leq BIAS < 0$ (underestimation) $0 < BIAS \leq 1.164$ (overestimation)	$-2.328 \leq BIAS < -1.164$ (underestimation) $1.164 < BIAS \leq 2.328$ (overestimation)	$BIAS < -2.328$ (underestimation) $BIAS > 2.328$ (overestimation)
	NMR	$-0.414 \leq BIAS < 0$ (underestimation) $0 < BIAS \leq 0.414$ (overestimation)	$-0.828 \leq BIAS < -0.414$ (underestimation) $0.414 < BIAS \leq 0.828$ (overestimation)	$BIAS < -0.828$ (underestimation) $BIAS > 0.828$ (overestimation)
	SBR	$-0.355 \leq BIAS < 0$ (underestimation) $0 < BIAS \leq 0.355$ (overestimation)	$-0.71 \leq BIAS < -0.355$ (underestimation) $0.355 < BIAS \leq 0.71$ (overestimation)	$BIAS < -0.71$ (underestimation) $BIAS > 0.71$ (overestimation)
PV	AMR	$0.667 \leq PV < 1$ (underestimation) $1 < PV \leq 1.333$	$0.334 \leq PV < 0.667$ (underestimation) $1.333 < PV \leq 1.665$	$PV < 0.334$ (underestimation) $PV > 1.666$

		(overestimation)	(overestimation)	(overestimation)
	UMR	$0.736 \leq PV < 1$ (underestimation) $1 < PV \leq 1.264$ (overestimation)	$0.472 \leq PV < 0.736$ (underestimation) $1.264 < PV \leq 1.528$ (overestimation)	$PV < 0.472$ (underestimation) $PV > 1.528$ (overestimation)
	IMR	$0.779 \leq PV < 1$ (underestimation) $1 < PV \leq 1.221$ (overestimation)	$0.558 \leq PV < 0.779$ (underestimation) $1.221 < PV \leq 1.442$ (overestimation)	$PV < 0.558$ (underestimation) $PV > 1.442$ (overestimation)
	NMR	$0.673 \leq PV < 1$ (underestimation) $1 < PV \leq 1.327$ (overestimation)	$0.346 \leq PV < 0.673$ (underestimation) $1.327 < PV \leq 1.654$ (overestimation)	$PV < 0.346$ (underestimation) $PV > 1.654$ (overestimation)
	SBR	$0.766 \leq PV < 1$ (underestimation) $1 < PV \leq 1.234$ (overestimation)	$0.532 \leq PV < 0.766$ (underestimation) $1.234 < PV \leq 1.468$ (overestimation)	$PV < 0.532$ (underestimation) $PV > 1.468$ (overestimation)