Temporal Topology in Continuous Glucose Monitoring: Midnight Segmentation Introduces Structural Measurement Artifact

Background and Aims

Continuous glucose monitoring generates physiologically continuous time-series data, yet most analytical frameworks segment these data at midnight according to calendar boundaries. Because glucose metabolism follows circadian processes rather than calendar time, this segmentation may introduce structural artifacts that disrupt temporal continuity.

Methods

An 89-day CGM dataset (25,536 readings) was analyzed using three temporal representations: (1) conventional 24-hour linear segmentation; (2) higher-resolution linear segmentation; and (3) a circular temporal representation preserving continuity across midnight. Information preservation was evaluated using Shannon entropy and continuity correlation between physiologically adjacent glucose measurements. Statistical significance was assessed using permutation testing to evaluate entropy differences across representations. Continuity correlation was computed using adjacent time-point pairing across midnight boundaries to quantify fragmentation effects. Data were preprocessed to remove sensor gaps and outliers; sensitivity analyses across bin widths and temporal alignments confirmed stability of findings.

Results

Circular temporal representation preserved significantly more information than conventional segmentation (3.56 vs 3.18 bits; +12.1%, $p < 0.001$). Midnight segmentation introduced edge artifacts at calendar boundaries that fragmented continuous overnight glucose dynamics into separate analytical intervals, reducing correlation between physiologically adjacent measurements by 2.8-fold. Increasing bin resolution without altering temporal topology produced no measurable improvement. Effect sizes were consistent across multiple temporal windows, confirming robustness of the observed information loss under conventional segmentation.

Conclusions

Calendar-based segmentation imposes artificial chronological boundaries on physiologically continuous processes. Treating the 24-hour cycle as a circular temporal topology preserves circadian continuity and corrects a structural analytical error in conventional CGM analysis, suggesting a biologically aligned framework for next-generation glucose data modeling.