

Fast-Rate Counters as Indicators of Signal Quality and Therapy Delivery in Subcutaneous Implantable Cardioverter-Defibrillators

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Subcutaneous implantable cardioverter-defibrillators (S-ICDs) prevent sudden cardiac death without intravascular leads, reducing complications and infection risk. However, inappropriate therapy remains a key limitation, often driven by poor signal quality, characterized by low R-wave amplitude and reduced R:T ratio, which leads to sensing errors and false tachyarrhythmia detection. This study evaluates fast-rate counter behavior as a marker of signal quality to distinguish true spontaneous tachyarrhythmias from sensing abnormalities. Remote monitoring data from S-ICD patients were analyzed to assess transitions to the tachycardia therapy profile (TTP), triggered when heart rate exceeds the programmed treatment zone. With adequate signal quality, malignant tachyarrhythmias produce sustained and organized rate patterns before therapy delivery. In contrast, poor signal quality yields erratic and intermittent detections, that may misclassify non-pathological rhythms. To account for variable transmission intervals, an exponential smoothing filter was applied to the fast-rate counter signal:

$TTP_{sm}(i) = \alpha \cdot TTP(i) + (1 - \alpha) \cdot TTP_{sm}(i - 1)$, where α ($0 < \alpha < 1$) controls the degree of temporal smoothing.

This study analyzed 318 records from the UNTOUCHED dataset [1]. Signals were classified using predefined low-signal quality criteria, with independent expert adjudication as the reference standard. Episodes identified as low quality by both the algorithm and the adjudicator were labeled true positives, while those identified by neither were considered true negatives.

Per-episode, sensitivity 84.8%, specificity 73.8%, and negative predictive value 97.7% for low signal quality detection. Mean TTP_{sm} differed significantly ($p < 0.01$) (Table 1). Low signal quality alters fast-rate counters, reflecting sensing performance and enabling early detection of signal integrity issues.

Table 1 Pairwise p-Values for TTP_{sm} by Group (Gr)

Gr	TP	TN	FP	FN
TP	--	$p<0.01$	0.087	0.389
TN		--	$p<0.01$	$p<0.01$
FP			--	0.096
FN				--

TP: True Positive; TN: True Negative; FP: False Positive; FN: False Negative;
One-way ANOVA with post hoc testing; $\alpha = 0.05$

[1] M. R. Gold *et al.*, "Postapproval Study of a Subcutaneous Implantable Cardioverter-Defibrillator System," *J Am Coll Cardiol*, vol. 82, no. 5, pp. 383-397, Aug 1 2023, doi: 10.1016/j.jacc.2023.05.034.