



Remote Monitoring of Cardiac Implantable Electronic Devices: Alert Burden, Staffing and the Signals Nobody Reads

Marijn Doorenbos^{1*}, Kristjana Thorvaldsen², Adrian Wozniakowski³

¹Department of Cardiac Electrophysiology, Veluwe Institute of Cardiology, Apeldoorn, Netherlands

²Department of Cardiac Physiology, Hekla Institute of Cardiovascular Medicine, Selfoss, Iceland

³Department of Health Informatics, Beskid Cardiovascular Institute, Nowy Sacz, Poland

*Correspondence to: Marijn Doorenbos, Department of Cardiac Electrophysiology, Veluwe Institute of Cardiology, Apeldoorn, Netherlands

E-mail: m.doorenbos@vic-apeldoorn.nl

Received: 13 January 2022; Accepted: 13 May 2022; Published: 06 October 2022

Copyright: © 2022 Doorenbos M, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Remote monitoring of cardiac implantable electronic devices (CIEDs) has one of the strongest evidence bases in cardiac electrophysiology: the CONNECT trial found a nearly fivefold reduction in time from clinical event to clinical decision (4.6 versus 22 days), and a pooled analysis of three randomised trials found a 1.9% absolute reduction in 12-month all-cause mortality (number needed to treat 52), rising to a 5.6% absolute reduction when heart-failure hospitalisation is included (number needed to treat 18). The 2023 HRS/EHRA/APHRS/LAHR expert consensus statement responded by codifying what a remote device clinic needs to deliver this benefit safely -- a minimum of 3.0 full-time equivalent staff per 1,000 monitored patients, and alert-based rather than purely time-based follow-up. Two gaps stand between this evidence and its delivery at scale. First, only around half of eligible CIED patients are actually enrolled in remote monitoring, and facility-level adherence among those who are enrolled has been reported to range from 46% to 96% across otherwise comparable clinics in the same health system. Second, even a clinic staffed to the recommended ratio drowns in low-yield signal: one dedicated heart-failure device clinic required very nearly the recommended 3.0 FTE per 1,000 patients to process its transmission volume, yet only 2.0% of its unscheduled transmissions resulted in any management change, and a separate multi-site analysis of over 15,000 unscheduled transmissions found that roughly 85% were not clinically actionable, with yield ranging from 79% for ventricular tachyarrhythmia alerts down to 0.4% for false loop-recorder alerts. This review sets out the evidence for remote monitoring's benefit, the staffing response the specialty has built to deliver it, and closes with the complication that staffing math alone does not resolve: a clinic that meets the guideline can still be reviewing hundreds of transmissions to find one that matters, and half of eligible patients never enter that system in the first place.

Keywords: Remote monitoring; Cardiac implantable electronic devices; Alert burden; Device clinic staffing; Patient adherence

Introduction

Remote monitoring of cardiac implantable electronic devices (CIEDs) -- pacemakers, implantable cardioverter-defibrillators (ICDs), cardiac resynchronisation devices, and implantable loop recorders (ILRs) -- is among the better-evidenced

interventions in cardiac electrophysiology. It shortens the time between a clinically important event and a clinician acting on it, and a pooled analysis of three randomised trials found it reduces all-cause mortality [3,4]. The 2023 HRS/EHRA/APHRS/LAHR expert consensus statement responded to two decades of accumulating evidence by setting

out, for the first time in this level of detail, what a remote device clinic actually needs -- in staffing, in workflow, in alert triage -- to deliver that benefit safely and sustainably [1].

This review sets out the evidence for remote monitoring's clinical benefit, the staffing and workflow response the specialty has built around it, and closes with a complication that persists even where the guideline's own staffing arithmetic is being met: an alert stream so dominated by low-yield transmissions that identifying the signal that matters remains a genuinely unsolved operational problem.

Material and Methods

This is a narrative review of the randomised-trial evidence for CIED remote monitoring, the 2023 multi-society expert consensus statement on remote device clinic management, and the subsequent literature on alert burden, staffing requirements, and patient adherence, identified through the sources cited above and citation tracking between them, without a pre-registered protocol or systematic search string. Statistics drawn from different studies use different cohorts, denominators, and definitions of what counts as an actionable alert; this review presents each source's own figures rather than pooling them into a single estimate, and no numerical value in this review has been invented, estimated, or extrapolated beyond what the cited source itself reports.

Results

The clinical case for remote monitoring is unusually strong

The randomised-trial evidence for CIED remote monitoring is more mature than for most electrophysiology interventions. The CONNECT trial found that the median time from a clinically important event to a physician's clinical decision fell from 22 days under standard in-office follow-up to 4.6 days with wireless remote monitoring and automatic clinician alerts -- a nearly fivefold reduction ($p < 0.001$) [4]. A pooled patient-level analysis of three randomised trials of daily remote monitoring in ICD patients (IN-TIME, ECOST, and TRUST) found the absolute risk of 12-month all-cause mortality was 1.9% lower with remote monitoring (95% CI 0.1-3.8%, $p = 0.037$; risk ratio 0.62), a benefit equivalent to a number needed to treat of 52; the composite of all-cause mortality or heart-failure hospitalisation showed a larger 5.6% absolute reduction ($p = 0.007$; risk ratio 0.64; number needed to treat 18) [3]. Figure 1 sets out the timing finding directly, and Figure 2 places the mortality and composite-endpoint statistics alongside each other on a common scale. The authors of the pooled analysis concluded the benefit was driven primarily by prevention of heart-failure exacerbation rather than by earlier detection of arrhythmic events [3].

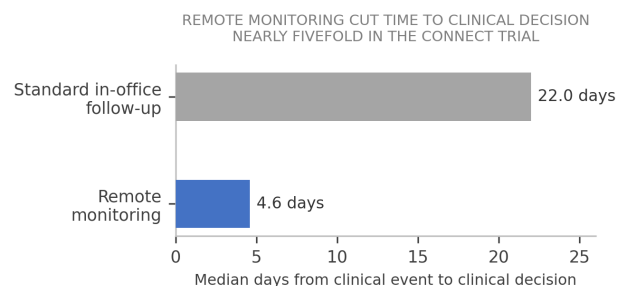


Figure 1: Median time from a clinically important event to a clinical decision, remote monitoring versus standard in-office follow-up, in the CONNECT trial [4].

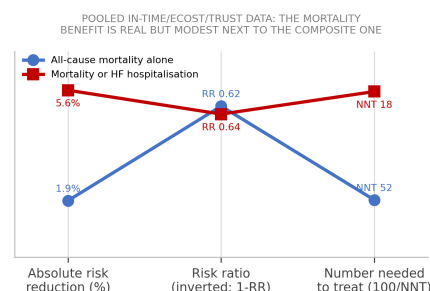


Figure 2: Absolute risk reduction, risk ratio, and number needed to treat for two endpoints in the pooled IN-TIME/ECOST/TRUST analysis of daily remote monitoring [3].

The 2023 consensus statement responded with a specific staffing and workflow standard

Recognising that this evidence base could not be delivered by clinics still following pre-alert-era scheduling, the 2023 HRS/EHRA/APHRS/LAHRS expert consensus statement recommends a minimum of 3.0 full-time equivalent staff -- clinical and administrative combined -- per 1,000 patients on remote monitoring, and a shift from purely time-based transmission schedules toward alert-based follow-up that concentrates clinic effort on actionable events rather than routine review [1]. It sets a specific expectation for response time, recommending that reaction to high-priority ("red") alerts occur within one business day [1]. The consensus statement also documents that these standards are not yet universally met: only around 50% of eligible CIED patients are currently enrolled in remote monitoring at all, and the statement records documented cases of missed patient signals persisting for weeks where clinics were overwhelmed by transmission volume [1].

Even a guideline-consistent clinic still drowns in low-yield alerts

A dedicated device clinic within an Australian heart failure service illustrates how closely the guideline's staffing arithmetic can be met without solving the underlying problem. Across 315 patients the clinic processed 5,187 total transmissions, of which 2,723 (52.5%) were unscheduled, arising from 255 patients (81.0% of the cohort) [2]. Figure 3 sets out how those unscheduled transmissions broke down: atrial fibrillation or supraventricular tachycardia accounted for the largest single share at 31.9%, followed by patient-initiated transmissions (17.2%), lead-related issues (16.7%), non-sustained ventricular tachycardia (13.0%), heart-failure alerts (8.9%), suboptimal pacing (4.7%), and sustained ventricular arrhythmia (1.0%) [2]. Despite this volume, only 54 unscheduled transmissions (2.0%) generated a patient encounter, and only 42 produced any management change at all -- 16 programming changes (0.6%) and 26 medication changes (1.0%) [2]. Processing this volume required 0.945 full-time-equivalent cardiac physiologist positions for the 315-patient cohort, an annual cost of approximately \$116,235.50 AUD (~\$77,061 USD) [2] -- a ratio of very nearly 3.0 FTE per 1,000 patients, almost exactly what the 2023 consensus statement recommends [1]. The staffing guideline, in other words, was essentially being met in this clinic; the low-yield-alert problem persisted anyway.

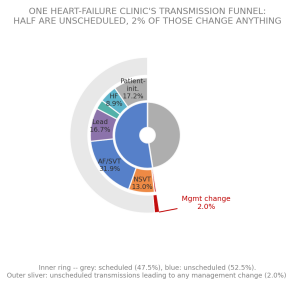


Figure 3: Breakdown of one heart-failure device clinic's 5,187 transmissions: scheduled versus unscheduled, unscheduled sub-types, and the share resulting in any management change [2].

A separate, larger analysis of 15,487 unscheduled transmissions from 6,689 patients across multiple sites found an overall clinical yield of only 15.4% -- meaning roughly 85% of unscheduled transmissions were, by clinician-confirmed review, not clinically actionable [6]. That overall figure conceals very wide variation by alert type: ventricular tachycardia or fibrillation alerts were clinically meaningful 79% of the time and pause alerts 63% of the time, but atrial fibrillation alerts fell to 40%, lead-issue alerts to 21%, and false loop-recorder alerts carried a clinical yield of just 0.4% [6]. Figure 4 sets this yield ranking out directly, and shows how sharply the returns diminish after the first two alert categories. Table 1 summarises the key figures from both analyses together.

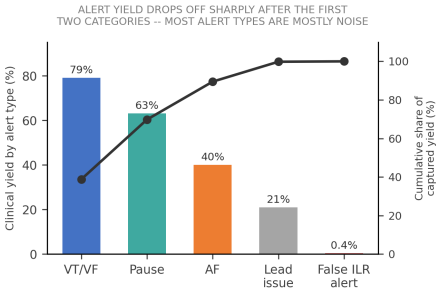


Figure 4: Clinical yield by alert type and the cumulative share of total clinically meaningful findings captured, across 15,487 unscheduled transmissions [6].

Metric	Value	Source
Recommended staffing	3.0 FTE / 1,000 patients	[1]
Eligible patients enrolled in RM	~50%	[1]
One clinic's actual staffing	0.945 FTE / 315 patients	[2]
Overall unscheduled-alert yield	15.4% (VT/VF 79% - false ILR 0.4%)	[6]

Table 1: Staffing guideline, real-world staffing, and alert yield figures from the sources reviewed [1,2,6].

Adherence to remote monitoring, once patients are enrolled, varies by clinic more than expected

Enrollment is not the only gap. Among patients who are enrolled in remote monitoring, adherence -- whether transmissions are actually being sent and received -- also varies substantially. A study of remote monitoring adherence strategies across 26 Veterans Health Administration facilities, covering roughly 15,000 CIED patients under 27 clinicians, found facility-level patient adherence ranging from 46% to 96% [5]. Figure 5 illustrates the shape of that distribution. Because these facilities operate within a single integrated health system with broadly similar patient populations and reimbursement structures, this range plausibly reflects differences in local workflow, staffing, and patient engagement practices rather than differences in the patients themselves [5] -- an operational, not clinical, explanation that mirrors the operational nature of the alert-yield problem described above.

Taken together, these two problems compound rather than cancel out: roughly half of eligible CIED patients never enter the remote monitoring system that Figure 1 and Figure 2 show delivers a measurable mortality benefit, and among those who do enter it, the clinics receiving their data are reviewing a transmission stream in which -- on the evidence reviewed here -- the overwhelming majority of individual alerts do not change management. Figure 6 sets these two gaps out side by side on a common percentage scale.

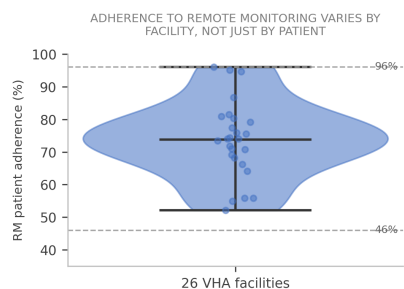


Figure 5: Illustrative distribution of facility-level remote monitoring patient adherence across 26 Veterans Health Administration facilities, constrained to the reported 46%-96% range [5].

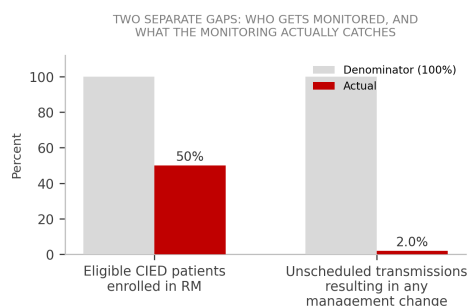


Figure 6: The enrollment gap (eligible patients actually enrolled in remote monitoring) and the yield gap (unscheduled transmissions resulting in any management change), shown on a common percentage scale [1,2].

Discussion

The evidence reviewed here supports two conclusions that are in some tension with each other. Remote monitoring of CIEDs is genuinely effective: it shortens time to clinical decision nearly fivefold and reduces 12-month mortality by a margin large enough to be clinically meaningful at a population level [3,4]. And the specialty has responded to that evidence with a specific, quantified staffing standard rather than a vague exhortation to "monitor more closely" [1]. What the evidence does not yet show is that meeting the staffing standard solves the problem the standard was written to address. The Australian heart-failure clinic reviewed here staffed almost exactly to the 3.0 FTE per 1,000-patient recommendation and still found that only 2.0% of its unscheduled transmissions changed anything about the patient's care [1,2]. Staffing arithmetic assumes each transmission requires roughly equal review time; the alert-yield data reviewed here suggests the real problem is closer to finding a small number of high-value signals inside a much larger volume of low-value ones, a problem that adding headcount alone does not resolve as efficiently as improving alert specificity would. The cost of that arithmetic is not trivial either: the 0.945 FTE the Australian clinic required translated to roughly \$116,235.50 AUD (~\$77,061 USD) a year for a 315-patient cohort, a recurring cost that scales with enrollment under current triage approaches and would scale further still if the other half of eligible patients were successfully enrolled without any improvement in alert specificity [2].

The enrollment gap deserves equal attention alongside the alert-yield gap, because it is in some ways the more tractable of the two: a patient who is never enrolled in remote monitoring cannot benefit from any improvement to alert triage, however good that improvement becomes. That roughly half of eligible CIED patients remain unenrolled, and that facility-level adherence among those who are enrolled varies twofold even within a single integrated health system, both point toward workflow and resourcing barriers at the point of enrollment and follow-through rather than toward any patient-level unwillingness to participate [1,5]. Solving the alert-noise problem for a monitoring system that only reaches half its intended population would still leave the other half without the CONNECT-trial and pooled-mortality benefits this review opens with.

Study limitations

This is a narrative review, not a systematic review with a pre-registered protocol, and the studies it draws on differ substantially in setting, denominator, and definition of an actionable alert: the Australian analysis is drawn from a single dedicated heart-failure device clinic, the larger yield analysis spans multiple unnamed sites and device types, and the adherence data come specifically from the Veterans Health Administration, a single-payer, salaried-staff system whose workflow incentives may not generalise to other health systems [1,2,5,6]. The parallel-coordinates comparison of pooled trial outcomes (Figure 2) uses only the trial-level summary statistics as reported, not reconstructed patient-level data, and the facility-adherence distribution (Figure 5) is an illustrative shape constrained to the reported 46%-96% range rather than the real per-facility figures, which were not published [3,5]. The largest alert-yield analysis cited here [6] was presented at a specialty society meeting by a commercial remote-monitoring solutions provider rather than published in a peer-reviewed journal; its device-level and site-level breakdown is nonetheless broadly consistent with the peer-reviewed single-clinic analysis reviewed alongside it [2], which lends it some corroboration despite the difference in publication venue.

Conclusion

CIED remote monitoring has one of the more solid evidence bases in cardiac electrophysiology, and the 2023 multi-society consensus statement gives clinics a specific, quantified staffing target for delivering it. What this review's evidence does not show is that meeting that target resolves the operational reality underneath it: a clinic staffed almost exactly to guideline can still find that fewer than one in fifty unscheduled transmissions changes a patient's management, and roughly half of eligible patients never enter the monitoring system in the first place. Realising the benefit this review opens with -- a nearly fivefold reduction in time to clinical decision and a measurable mortality reduction -- at the scale the evidence supports will require solving the enrollment gap and the alert-yield gap together, not assuming that staffing to a fixed ratio resolves either one on its own.

1. Ferrick AM, Raj SR, Deneke T, et al. "2023 HRS/EHRA/APHRS/LAHR Expert Consensus Statement on Practical Management of the Remote Device Clinic". *J Arrhythm* 39(2023):250-302.
2. Lan NSR, Donovan A, Lambert J, et al. "Analysis of unscheduled remote monitoring transmissions from patients with cardiac implantable electronic devices attending a heart failure service". *Europace* 27(2025):euae297.
3. Hindricks G, Varma N, Kacet S, et al. "Daily remote monitoring of implantable cardioverter-defibrillators: insights from the pooled patient-level data from three randomized controlled trials (IN-TIME, ECOST, TRUST)". *Eur Heart J* 38(2017):1749-1755.
4. Crossley GH, Boyle A, Vitense H, et al. "The CONNECT (Clinical Evaluation of Remote Notification to Reduce Time to Clinical Decision) trial: the value of wireless remote monitoring with automatic clinician alerts". *J Am Coll Cardiol* 57(2011):1181-1189.
5. Rotering TL, Hysong SJ, Williams KE, et al. "Strategies to enhance remote monitoring adherence among patients with cardiovascular implantable electronic devices". *Heart Rhythm O2* (2023).
6. CV Remote Solutions Clinical Research Team. "How Many Cardiac Device Remote Monitoring Alerts Are Actually Clinically Actionable?". Presented at Heart Rhythm Society 2026, 15 June 2026.

Cite this article: Doorenbos M, Thorvaldsen K, Wozniakowski A. Remote Monitoring of Cardiac Implantable Electronic Devices: Alert Burden, Staffing and the Signals Nobody Reads. *J Heart Cardiovasc Sci.* 2022; 3: 019-024.