Clinician use of data elements from cardiovascular implantable electronic devices in clinical practice

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BACKGROUND Cardiovascular implantable electronic devices (CIEDs) capture an abundance of data for clinicians to review and integrate into the clinical decision-making process. The multitude of data from different device types and vendors presents challenges for viewing and using the data in clinical practice. Efforts are needed to improve CIED reports by focusing on key data elements used by clinicians.

OBJECTIVE The purpose of this study was to uncover the extent to which clinicians use the specific types of data elements from CIED reports in clinical practice and explore clinicians' perceptions of CIED reports.

METHODS A brief, web-based, cross-sectional survey study was deployed using snowball sampling from March 2020 through September 2020 to clinicians who are involved in the care of patients with CIEDs.

RESULTS Among 317 clinicians, the majority specialized in electrophysiology (EP) (80.1%), were from North America (88.6%), and were white (82.2%). Over half (55.3%) were physicians. Arrhythmia episodes and ventricular therapies rated the highest among 15 categories of data presented, and nocturnal or resting heart rate and heart rate variability were rated the lowest. As anticipated, clinicians specializing in EP reported using the data significantly more than other specialties across nearly all categories. A subset of respondents offered general comments describing preferences and challenges related to reviewing reports.

CONCLUSION CIED reports contain an abundance of information that is important to clinicians; however, some data are used more frequently than others, and reports could be streamlined for users to improve access to key information and facilitate more efficient clinical decision making.

KEYWORDS Cardiovascular implantable electronic device; Clinical decision making; Digital health data; Remote monitoring; Survey methods

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Introduction

Cardiovascular implantable electronic devices (CIEDs) are critical for monitoring and treatment of complex cardiac conditions, and the number of implants has been increasing worldwide.[1,2] Clinicians who care for patients with CIEDs monitor the status, function, and diagnostics captured by the device to identify and make decisions for follow-up care. Remote monitoring (RM) of CIED data has increased over the past 2 decades.[3,4] RM of CIEDs reduces the time from clinical event to treatment and follow-up.[5] However, the abundance of data captured by CIEDs is difficult to manage, for multiple reasons. For example, there are several different types of CIEDs (eg, pacemakers [PMs], implantable cardioverter-defibrillators [ICDs], and cardiac resynchronization therapy [CRT] devices), as well as multiple manufacturers of each type, all with different data formats. There is a need for industrywide standardization and interoperability to ensure patient safety, simplify workflows, and improve efficiency.[6,7] Another issue is the overabundance of alerts. Devices are programmed to generate alerts that are intended to prevent worsening outcomes by drawing provider attention to actionable events; however, in practice, many alerts ultimately are nonactionable or nonurgent, increasing clinical burden and taking time away from alerts that are clinically relevant.[8,9]

Generally, CIED reports are managed by trained (and often CIED-certified) professionals, who review the data to distinguish clinically relevant information and follow up

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KEY FINDINGS

- From a list of 15 categories of CIED data elements, clinicians reported using data related to arrhythmia episodes, ventricular therapy, and atrial fibrillation most often in clinical practice.
- Overall, EPs reported a higher frequency of use of CIED data elements than non-EPs, with statistically significant differences between the two groups among all categories of data elements except for heart rate variability, which both groups reported using less frequently than other data elements.
- The majority of additional key data elements that were provided as open-response comments were related to routine monitoring (data that ensure the device is functioning properly).
- The majority of other comments from survey respondents about CIED reports critiqued the amount of information, organization, presentation, and navigability of the data in the reports.

with clinicians and patients as necessary; however, specific workflows vary widely across institutions.[4,10,11] Although management of CIED data is specialized, patients who have CIEDs often receive care from multiple clinicians, including cardiologists who do not specialize in electrophysiology (EP). Studies have shown relatively low familiarity of ICD guidelines among general cardiologists and other physicians.[12,13] Although cardiologists overall have greater understanding of these guidelines than other types of physicians,[13,14] there are barriers to CIED guideline adherence even among different specialties of cardiologists.[15] Although targeted provider education is identified as a primary strategy to improve clinicians' knowledge and confidence surrounding CIED management,[13–15] it is also important to improve the accessibility and interpretability of relevant data. This might include reports with messages from the CIED specialty clinic, which could be used by general cardiologists and noncardiology specialists to better support patients throughout the trajectory of care.

CIED data and clinical decision making

Despite the complexity of CIED reports due to the large amount of data, abundance of alerts, proprietary algorithms, and varying data formats used by device companies, there has been minimal research to understand end-user perspectives or optimize report usefulness for clinicians. Efforts to standardize the vocabulary and nomenclature for the CIED data elements captured and transmitted by CIEDs have resulted in the Institute of Electrical and Electronics Engineers (IEEE) standard 11073-10103.[7] This dataset has been recently revised by the Heart Rhythm Society (HRS) Interoperability Workgroup and is essential for use across vendors and middleware systems to present data in a standardized manner. It is important to understand the frequency with which clinicians use each CIED data element in clinical practice to improve usability and navigability of the reports, address identified gaps in provider knowledge, and allow providers to leverage these data in clinical decision making while optimizing cost, efficiency, and health outcomes. As a first step toward this end, the purpose of the present study was to assess (1) clinicians' perceptions of the amount of data in the reports; and (2) how frequently clinicians use certain data elements in their clinical practice.

Methods

Study design

The Parkview Mirro Center for Research and Innovation, in collaboration with the HRS Interoperability Workgroup, conducted a web-based, cross-sectional survey study for the assessment and understanding of clinicians' perceptions as well as provider usage of RM or in-office interrogation reports for ICDs and PMs, including CRT defibrillators and CRT PMs (herein referred to collectively as CIED reports) in clinical practice. The study was determined Exempt by Parkview's Institutional Review Board.

Survey development

Research team members developed a 20-item survey. The main question on the survey, *How frequently do you use the following information from the remote monitoring and/or in-office interrogation reports in clinical practice?*, included 15 categories of device data to which participants responded on a 5-point Likert scale (1 = never, 5 = very often). Two questions assessed the use of CIED data reports. The first question asked whether they use the reports *frequently, sometimes,* or *never* in clinical decision making. The second question asked whether the amount of information in the report is *not enough, just right,* or *too much.* Two open-ended questions for additional key data elements and other additional comments about the reports also were included, as well as demographics and clinician characteristics (eg, position and specialty, years in practice, number of patients with ICDs or PMs). Items were revised through several iterations, incorporating feedback from clinician experts and members of the HRS Interoperability Workgroup, with the goal of streamlining the survey into a form that would be easy for clinicians to complete quickly.

Recruitment

Recruitment was completed by snowball sampling methods through digital venues aimed toward clinicians, both public and society-affiliated, including Heart Rhythm Society Community Forum (Newsletter and Twitter); the ACC Indiana Chapter Newsletter; MedAxiom; and Canadian Heart Rhythm Society. HRS members were also invited to share the survey through their individual and professional networks, and researchers asked device vendors and third-party middleware companies to share the survey link with their clients. The survey was provided in English only.

Distribution was not limited geographically; however, no efforts were made to gather responses from any specific locations. Survey distribution began in March 2020 and ended in September 2020. All survey responses were anonymous, and participants were not compensated. Because the development of the survey was a collaborative effort with experts in the field, it is possible that some participants may have seen versions of the survey before deployment.

The survey was distributed using Microsoft Forms, an online survey tool hosted on the first author's hospital system's secure Office 365 platform. The form included a brief description of the purpose of the survey, and 2 questions to confirm that (1) participants were health care providers and (2) they agreed to volunteer to take the survey. Additionally, if participants did not have patients in their care who have ICDs or PMs, or did not use CIED reports, they were not asked the main questions described and instead were directed to the demographic and characteristic sections at the end of the survey.

Analysis

Descriptive statistics were calculated using Microsoft Excel. Independent *t* tests were conducted to compare use of CIED data elements between EP and non-EP providers. Satterwaithe degrees of freedom were used, and *P* values were adjusted for multiple comparisons using the false discovery rate. Three authors (CD, AC, and TA) coded the 2 open-ended response questions using a standard inductive coding technique and discussed categories and themes that emerged to ensure agreement among coders.

Results

Participant characteristics

Of the total 335 responses, 18 were removed from final analyses for the following reasons: 6 participants answered that none of the patients for whom they were responsible for clinical care had an ICD or PM, and 2 indicated that their patients do have ICDs or PMs but did not complete any remaining questions. Of the remaining participants (n = 327), 10 reported that they do not use information from CIED reports in clinical decision making. These 10 participants included physicians (60%), advanced practice providers (30%), and 1 medical assistant/patient engagement specialist. Of these, 9 reported how many patients with devices were in their care, and the number ranged from 20–1000.

After removal of these 18 responses, the final sample included 317 participants who reported having an average of 2151 patients with ICDs and PMs (range 4–75,000; median 700). Respondents were mostly physicians (55.3%), white (81.9%), and located in the United States (79.4%). Most clinicians specialized in EP (80.1%), with 4 "cardiac rhythm or device specialists" included in this group. Participant characteristics are listed in Table 1.

Table 1 Participant characteristics (N = 317)

Characteristic (no. of responses)	n (%)
Position (n = 313)	
Physician	173 (55.3)
Advanced practice provider	48 (15.3)
Nurse	43 (13.7)
Technician	38 (12.1)
Other	11 (3.5)
Years in position (n = 315)	
≥21	102 (32.4)
11–20	101 (32.1)
0–10	112 (35.6)
Area of specialty (n = 316)	
Electrophysiology	253 (80.1)
General cardiology	39 (12.3)
Interventional cardiology	13 (4.1)
Advanced heart failure and transplantation	5 (1.6)
Other specialty	6 (1.9)
Primary work setting (n = 257)	
Academic medical center	131 (51.0)
Nonprofit health system	75 (29.2)
Private practice or for profit	32 (12.5)
Industry	10 (3.9)
Remote monitoring	6 (2.3)
Multiple settings	3 (1.2)
Continental location (n = 316)	
North America	280 (88.6)
Europe	25 (7.9)
Asia	6 (1.9)
Other	5 (1.6)
Hispanic, Latino, or Spanish origin (n = 311)	
No	302 (97.1)
Yes	9 (2.9)
Race (n = 304)	
White	250 (82.2)
Asian	38 (12.5)
Black or African American	8 (2.6)
Multiple races	5 (1.6)
Other/unknown	3 (1.0)
Sex (n = 308)	
Male	162 (52.6)
Female	146 (47.4)
Age (y) (n = 311)	
18–24	1 (0.3)
25–34	19 (6.1)
35–44	95 (30.5)
45–54	81 (26.0)
55–64	84 (27.0)
65–74	31 (10.0)

Participant use and opinions regarding adequacy of information in the CIED reports

Most participants reported using the information in the reports "frequently" for clinical decision making (87.1%), and that the amount of information provided was either "just right" (54.6%) or "too much" (34.3%), suggesting that CIED reports currently have adequate information for clinicians to use in practice (Table 2).

Frequency of use of CIED data elements for clinician decision making

The number of clinicians who reported frequency of use for each of the 15 categories of device data ranged from 312–316 (1 participant did not answer any category). Overall,

Table 2 Use of CIED data reports (N = 317)

How often CIED data are used for clinical decision making (n = 317)	
Frequently	276 (87.1)
Sometimes	41 (12.9)
Adequacy of amount of information in the report (n=315)	
Not enough	35 (11.1)
Just right	172 (54.6)
Too much	108 (34.3)

Values are given as n (%).
CIED = cardiovascular implantable electronic device.

the 3 highest-rated data categories for frequency of use were arrhythmia episodes, ventricular therapy, and atrial fibrillation (A-fib), with average rating scores of 4.8, 4.8, and 4.6, respectively. The lowest-rated data were nocturnal or resting heart rate and heart rate variability, with average rating scores of 2.8 and 2.7, respectively.

Of note, only about one-third of participants reported using the data often or very often for the following 6 categories: proprietary measures (38.5%); thoracic impedance (37.3%); activity (31.4%); proprietary alerts (35.5%); nocturnal heart rate (22.9%); and heart rate variability (22.5%). Conversely, over two-thirds of participants reported using the data often or very often for the remaining 9 categories: arrythmia episodes (96.8%); ventricular therapies (96.5%); A-fib data (91.3%); biventricular or left ventricular pacing (91.1%); battery (85.1%); electrocardiograms (EGMs) (83.1%); lead integrity (82.2%); right ventricular pacing (83.1%); and mode switching (77.0%) (Figure 1).

Overall, the results suggest that CIED data are used more frequently in clinical practice when they pertain to immediate needs and diagnostics (eg, arrhythmia episodes), rather than when they provide less urgent information that is not critical for decision-making, such as heart rate variability. The most frequently used data (arrhythmia episodes and therapies applied), for example, are directly related to the lifesaving function of the device.

Frequency of use of CIED data elements for clinical decision making among EP and non-EP clinicians

Among the 316 participants who both reported their clinical specialty and answered at least 1 of the frequency of use items, 252 (79.7%) were in the EP category, and 63 (19.9%) identified their specialty as general cardiology, interventional cardiology, advanced heart failure (HF) and transplantation, or other (these 63 are herein referred to as the "non-EP" group).

The total number of responses from the EP group ranged from 249–252 across the 15 items, and the total number of responses from the non-EP group across the 15 items ranged from 60–63. Compared to the non-EP group, the EP group members, on average, indicated that they used each of the data elements more often (Figure 2). When looking at specific categories, the largest differences were found between groups for lead integrity, EGMs, and battery. For the EP

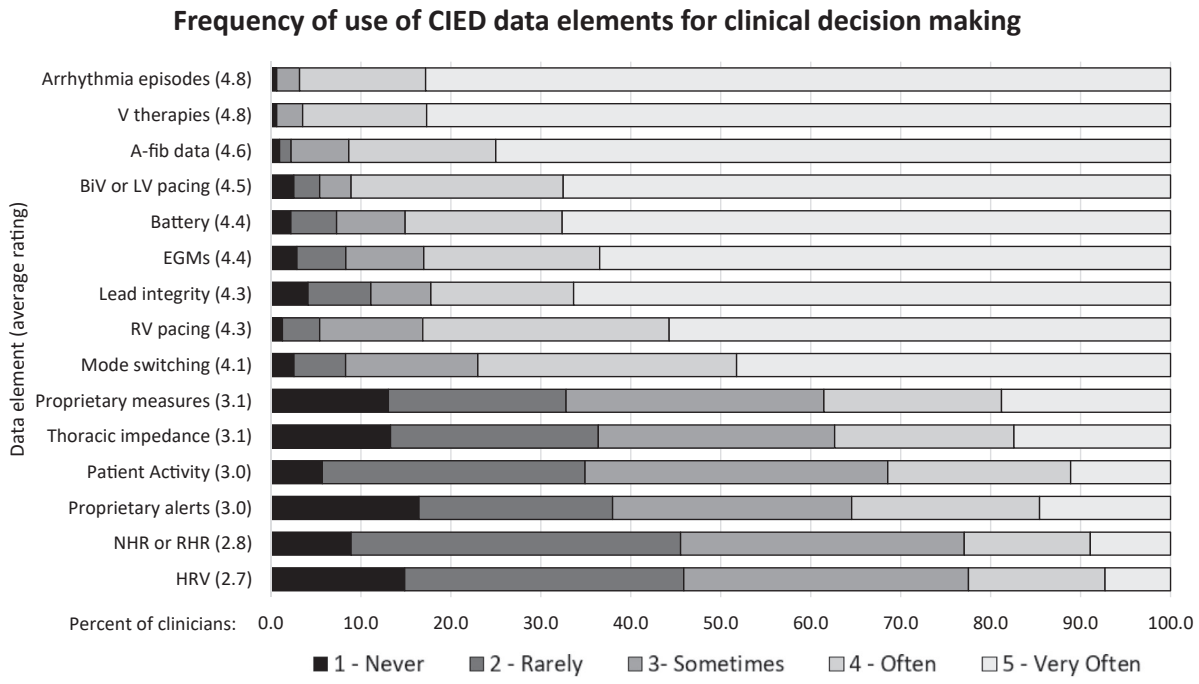

Figure 1 Participant responses to how often they use certain cardiovascular implantable electronic device (CIED) data elements for clinical decision making. A-fib = atrial fibrillation; BiV = biventricular; EGM = electrocardiogram; HRV= heart rate variability; LV = left ventricular; NHR = nocturnal heart rate; RHR = resting heart rate; RV = right ventricular; V = ventricular.

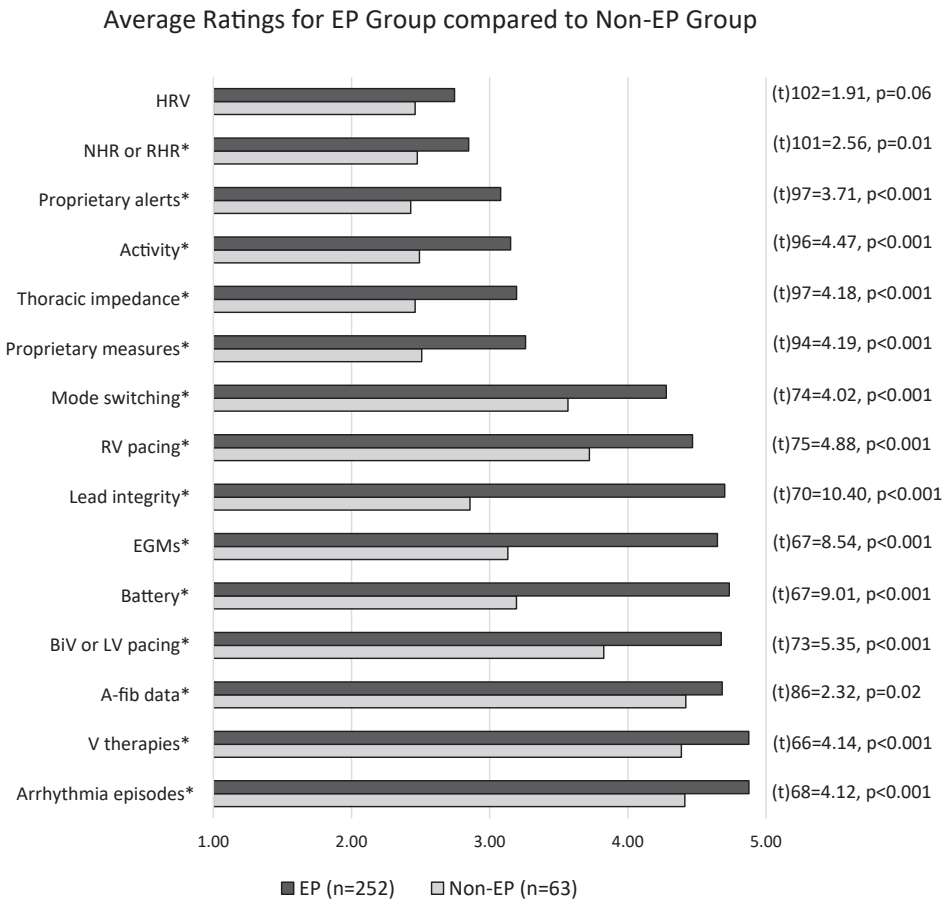

Figure 2 Average ratings for how often electrophysiology (EP) and non-EP clinicians use certain cardiovascular implantable electronic device data elements for clinical decision making. The scale ranged from 1 to 5, where 1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = very often. *Asterisk* indicates statistical significance in difference between the 2 groups for the given category. Abbreviations as in Figure 1.

group, these were among the 7 highest-rated data categories, which all were rated at least 4.65 of 5, suggesting high utility. In contrast, for the non-EP group, these 3 categories had an average rating of approximately 3. Neither EP nor Non-EP clinicians reported using heart rate variability often, and this was the only category that was not significantly different between the 2 groups. For the non-EP group, the highest-rated data categories for frequency of use were arrhythmia episodes (4.41), ventricular therapy (4.39), and A-fib data (4.42), corroborating these data as *key data elements* in the care of patients with CIEDs.

Participant input and feedback regarding CIED data reports

Two open-ended questions were included in the survey to capture key data elements that were not already covered in the previous question, as well as any additional comments about the CIED reports. After removing responses such as "none" or "N/A," 128 responses to both questions from 101 participants were included in the qualitative analysis. Nearly half of participants who answered either or both questions were physicians (48.5%). The majority specialized in EP (91.1%) and had 11 or more years of experience (68.3%).

Key data elements and desired information specified by participants

The open-ended responses contained a total of 160 key data elements from 75 participants. Notably, 14 participants indicated that premature ventricular contractions (PVCs) are a key data element. A small number of respondents mentioned underlying rhythm or native rhythm (n = 4), PM-dependent status (n = 3), and presence of noncardiac noise (n = 3). Four respondents described relevant clinical data that are not CIED data elements, including notes from previous visits, last reset date, reason for implant, and symptom correlation with arrhythmia.

The remaining items were grouped into categories based on similarity, resulting in 7 categories pertaining to key data elements and 1 category consisting of desired data and information (Table 3). The emergence of these categories in the open-ended responses further emphasizes their importance. The most frequently reported data elements were related to routine monitoring data to ensure that the device is functioning properly. The second most common category included data related to heart rate histograms. The desired data and information category revealed specific items of interest that could make the reports more useful, suggesting that the presentation of data could be improved to enhance

Table 3 Categories of key data elements and desired data from open-ended questions

Category	Types of data included	No. of participants
Routine monitoring data	• Settings • Programming • Tracking rates • Trending graphs • Test results	31
Heart rate histogram data	• Rate histograms • Rate response	10
A-Fib related data*	• A-Fib burden • Rate during A-Fib	10
Arrhythmia episodes*	• EGMs • Amount of AF/SVT/VT after drug therapy and ablative procedures	6
Device information	• Implant information • Type of device	6
HF-related data	• Effective CRT pacing (assumed to be based on CRT and/or LV pacing %) • A-fib or PVC-triggered CRT	5
Lead integrity*	• Lead alerts • V-V sensing	4
Battery status*	• ERI • Premature depletion alerts	4
Desired data and information	• Self-report of recall surveillance • Assessment of underlying rhythm • Linking device data to patient clinical status • More details on VT therapies such as how many episodes, duration, and cycle length • PVC burden in percentage • AF data outlined more clearly • Presenting EGM for symptomatic patients • Baseline EGM morphology printed with EGMs for arrhythmia interpretation • Sensitivity/number of appropriate or inappropriate therapies	8

Four categories emerged that were determined to be directly related to the data elements presented in the previous question on the survey, and were noted with an asterisk (A-fib related data*, arrhythmia episodes*, lead integrity*, and battery status*).

A-fib, AF = atrial fibrillation; CRT = cardiac resynchronization therapy; ERI = estimated replacement interval; EGM= electrocardiogram; HF = heart failure; LV = left ventricular; PVC = premature ventricular contraction; SVT = supraventricular tachycardia; VT = ventricular tachycardia; V-V = interventricular.

clinical interpretation. This concept is explored further in the section on Presentation and organization of the reports.

Fifteen responses were not included in the table because they did not fall under a particular category (as they were single responses and/or unclear as to what they were referring) (see Supplemental Appendix for the full list of items).

Presentation and organization of the reports

Responses that included additional comments about CIED reports (ie, beyond identifying key data elements) were organized thematically and are summarized here. Some quotes have been lightly edited for clarity.

The majority of responses critiqued the amount, organization, and/or presentation of the data. Very frequently, respondents expressed that these reports contain an excessive amount of information that is not optimally organized. As 2 participants explained:

- [The CIED reports] are not organized at all. It's just a vomitus of data.
- Many reports have TOO many graphs and data jumbled together or have important data under layers of other information.

Often, participants felt this limited their ability to efficiently navigate, evaluate, and take appropriate clinical action on the data:

- Sometimes reports are information overload and it's difficult to narrow down the info you really need.
- It is too time consuming, and the device companies do not have adequate support for the ton of data they dumped on EPs.
- It takes doing your "10,000" remotes to become proficient at mining out the useful pieces of information.

A few respondents also mentioned specific pain points that inhibit efficiency, such as managing alerts and redundancy:

- Excessive alerts. Need a standardized protocol to deal with the numerous alerts received daily.
- There is a lot of repetitive data (eg, mode switching, PAC [premature atrial contraction] burden, AT [atrial tachycardia]/AF [atrial fibrillation] episodes). Also, device settings are often shown repeatedly in several places.

Conversely, some respondents also noted that reports are missing important information:

- Some reports…have detailed info but not really what one needs. Like, if there is an event—how long it happened and any available EGMs.
- In-person device checks provide appropriate information; however, some remote monitor reports are lacking in regards to arrhythmia data.

At times, these issues were exacerbated by differences across manufacturers, with some clinicians expressing preferences for certain vendors' reports over others:

- Each company has various data delivered. Some too much, others, not enough.
- One of the more challenging aspects, especially when training new nurses, is the variable presentation of data from different vendors, as well as the sheer volume of data.
- Some companies do this better than others, but there is a lot of extra data in some of the reports that makes them

unmanageable. An example would be a daily list of auto-threshold values, rather than a graph of the same data.

A few clinicians further elaborated on their workflows or background in regard to navigating and utilizing these reports. For example:

- It is very helpful that our device clinic nurses pre-screen and write the reports. Otherwise, this would not be do-able.
- Reports need to be more user friendly. I am not an EP cardiologist, so they need to be easier for me to find the values/data I want.

Some clinicians provided direct suggestions for how reports could be improved to increase efficiency and actionability. Several expressed a desire for increased standardization across vendors or easier access to a summarized overview of the data, for reasons such as "*a common format between manufacturers would make the data easier to evaluate.*" Others advocated for adoption of a third-party vendor system or centralized platform:

- I would appreciate if all manufacturers agree to send their daily data to third-party remote monitoring platforms.
- A [free] summarized report should be available to any clinician at any time through a central feeding system.

Additionally, some clinicians felt that greater efficiency could be achieved by creating reports that leverage artificial intelligence and/or are more tailored and customizable, thus limiting the amount of data that one must sort through:

- It is essential to have an algorithm-based pre-selection of transmissions needing attention. I do not want to look at normal values for device integrity or meaningless transmissions.
- It would be good to develop more functional reports that are customized to show certain pertinent information based on the patient's device and clinical characteristics.

Overall, the respondents identified various shortcomings of current reports that impact their ability to take clinical action from the data contained within them, providing insight to support future design work to address these concerns.

Discussion

Clinicians' perceptions of CIED reports and most frequently used data elements

Most of the clinicians who responded to the survey were in North America and specialized in EP, and over half were physicians. Results suggest that clinicians generally find CIED reports to contain the right amount of information, and they use much of the data frequently in clinical practice, underscoring its importance. However, a notable number of clinicians find that the reports have too much data, even expressing that this "excessive" or "overwhelming" amount of data is detrimental to their ability to utilize this information clinically. These findings justify the need to focus efforts on improving the interpretability of the reports to facilitate more efficient reviewing of the abundance of data, perhaps starting with the most frequently used data categories: arrhythmia episodes, ventricular therapy, and A-fib data. The reasons for frequency of use were not examined in this study; however, these highest-rated data elements are critical health information that are most directly related to the therapeutic purpose of the device. Other information related to device functioning (eg, battery status and lead integrity, which were rated slightly lower) also are important to monitor, but they may not need to be reviewed unless there is an alert or concern. The organization of these data is also important, as clinicians noted difficulties related to navigating the reports and finding the data they need. Improved organization of reports could impact how often specific CIED data are used in clinical practice.

The open-ended questions revealed additional key data elements that were important to clinicians but were not included specifically in the main question on the survey, including routine monitoring data (settings and programming), PVCs, and heart rate histograms. Additional follow-up is necessary to understand *when* certain data elements are most important, and *for whom* (eg, clinicians in a device clinic may have specific needs and uses for data during the trajectory of RM evaluations). Although only a small number of clinicians provided open-ended responses related to desired data or information, these findings are important to explore in user-centered design work to understand ideal ways to present the data (eg, PVC in percentage), provide more details (eg, data related to ventricular tachycardia therapy), or link device data to clinical health status.

Less frequently used CIED data elements

The lowest-rated data elements for frequency of use may not be as urgent or critical; however, these data could be leveraged through more sophisticated tools and algorithms. For example, the combination of patient activity, thoracic impedance, nocturnal heart rate, and heart rate variability has been shown to predict hospitalization.[16] There are existing proprietary data formats and algorithms from competing device vendors, many of which are specifically related to HF. Although there is increasing promise for CIED data elements to be useful predictors of HF decompensation, these algorithms are not greatly supported by clinical evidence for reduction in mortality and hospitalizations.[17] Although guideline-directed medical therapy for HF includes indication for CIEDs,[18] it is possible that HF datapoints from CIEDs are underutilized due to an absence of evidence-based guidelines or inexperience in the interpretation of these data in clinical practice.[19] Lower frequency of use of these data elements may also imply that these data are not well integrated into clinical decision-making workflows, are irrelevant to the majority of clinical cases, or are impractical for frequent monitoring, among other reasons that require further exploration.

Differences between EP and non-EP clinicians

In both our qualitative and quantitative analyses, some differences emerged between respondents who were

electrophysiologists and those who were not (ie, general cardiologists or other specialties), perhaps due to the differences in expertise and clinical needs, that is, these data may be more relevant to the workflow and decision-making of EPs than non-EPs. For example, non-EP cardiologists may not need to review lead information and battery status as closely as EPs and clinicians specializing in device follow-up who are more directly involved in device functionality and replacement, and there may be an understanding within a comprehensive care team that these data will be reviewed by a specialist. Additionally, EGMs require specialized training in EP to interpret, so it is understandable that non-EPs would not necessarily review them.

A few non-EPs specifically noted in their open-ended responses that they felt they had greater difficulty navigating and understanding reports due to their lack of specialization in this area, supporting findings in previous research.[15] This further underscores the importance of tailored, summarized, and actionable data to help all providers make efficient and informed clinical decisions, regardless of specialty, as patients with CIEDs are frequently treated by general cardiologists and other non-EP providers (eg, internists or geriatricians) who have varying attitudes and levels of knowledge about CIEDs[20] and may require more support to understand and utilize these data optimally. Although many non-EPs may not need to utilize CIED reports as frequently or comprehensively as EPs, having an easily digestible view of important datapoints would be useful for facilitating conversation and coordinating care for patients with these devices, particularly as patient access to electronic health record data continues to increase.

Challenges to using CIED reports

Our qualitative findings, in which respondents frequently reported that the amount of data was overwhelming and/or unorganized, suggest that frequency of use may be impacted by how data presentation facilitates or impedes clinicians' ability to locate and interpret certain datapoints. These challenges with accessing organized, comprehensive data in a timely manner are similar to those found in other areas of health technology (eg, electronic health records),[21] representing a need for greater understanding of usability issues related to abundant and complex health data. As such, there are opportunities to increase the frequency with which providers are able to utilize CIED data by creating more navigable, relevant reports through user-centered design. The use of IEEE data elements by all vendors and the ability for middleware systems to receive and present data in a standardized format are important parts of accomplishing these goals. Table 4 lists the major pain points, describes the challenges, and articulates perceived needs and suggested actions to address the findings that emerged from the survey.

Future directions

Clinicians are often overwhelmed by CIED data and reports, and work is ongoing to increase efficiency, navigability, and utility of data. As the need for remote cardiac care has increased in recent years and was fast-tracked during the pandemic,[24] we are faced with an imminent need to optimize the usability of CIED and RM reports. Future work should use the findings from this study regarding the most frequently

Table 4 Pain points, challenges, perceived needs, and suggested actions for improving CIED reports based on qualitative findings

Pain points	Challenges	Perceived needs	Suggested actions
• Varied presentation of information across different vendor platforms	• Lack of standardization among vendor platforms makes it difficult to evaluate reports	• "Vendor-neutral" platforms that integrate data into a streamlined, organized, and standardized report[7,22]	• Evaluate the efficacy of vendor-neutral platforms to optimize their implementation and use
• Usage of proprietary data elements or alerts	• Different formats for data from certain vendors seem to be preferable over others	• Presentation of key data elements in a standardized way, allowing clinicians to access the data they need in a consistent, optimal format	• Establish agreement on IEEE dataset among device vendors, engineers, and clinicians
• Excessive alerts	• Too many alerts make it difficult to take action when needed	• Support from the device companies to filter alerts that are important • Clinical guidance for prioritizing alerts	• Refine programmable alerts and workflow for managing alerts[8]
• Abundant data that are overwhelming and unorganized	• Key data elements vary based on individual patient needs, and important information can be buried in the report • CIED-related knowledge and clinical information needs vary based on clinicians' role and specialty	• Useful organization of data, such as a problem-oriented view,[23] such as prioritizing HF data (impedance, activity) for CIED patients with HF, AF data for those with AF • Tailorable options, such as the ability to filter data easily or build a dashboard to display data per patient and clinician needs	• Leverage existing research and conduct user-centered design research with industry partners to develop design options based on direct end-user input

CIED = cardiovascular implantable electronic devic; IEEE= Institute of Electrical and Electronics Engineers; other abbreviations as in Table 3.

used data elements as a starting point for user-centered design research with clinicians to better understand their information needs. Furthermore, as patients with CIEDs have expressed desire to access data from their device[25] in a way that is meaningful and easy to interpret,[26] subsequent work should focus on addressing the needs of multiple stakeholders involved in reviewing and utilizing CIED data.[27,28] A shared interface with separate patient and provider views could bridge the gap between what patients want to see and what clinicians find clinically relevant and meaningful, while also allowing clinicians to access the patient-facing interface to address questions.[28]

Study limitations

Although clinicians across 6 continents responded to the survey, the respondents were primarily from North America white, and English-speaking (as the survey was only provided in English). The survey link was distributed in cardiology communities with no specific effort to ensure representation across certain communities, obtain a global reach, or enroll a diverse sample of clinicians that represents the global population of health care providers.

Although the survey provides valuable insight into which of the numerous available CIED datapoints are actually used in practice, the survey did not account for the specific cardiac conditions and types of devices that would impact the frequency with which clinicians would utilize CIED data within their patient population. Additionally, we did not operationally define "use" or ask respondents to expand on the ways in which they use the data (eg, taking direct clinical action, consulting with other clinicians). However, the brevity of the survey may have facilitated our ability to capture more responses that provide a high-level understanding of the frequency of use of CIED data elements.

Conclusion

The present study investigated clinicians' frequency of use of CIED data in clinical practice and revealed preferences and challenges with using CIED reports in clinical decision-making. The survey findings suggest that CIED data reports are comprehensive, providing an abundance of important information, but that improvements can be made to the organization of reports to enhance use of data in clinical practice. Key data elements include actionable data that are of immediate health concern, such as arrhythmia episodes and ventricular therapies; however, there are many data elements that may be considered important but are presently difficult to use based on the amount of data, presentation of data, and lack of standardization across manufacturers. Future work should consider these factors within the context of the end-user's level of specialization, knowledge, and data needs. For electrophysiologists and cardiac device care teams, this may include a refined and improved organization of reports with greater standardization across vendors, easy-to-find key data elements, and facilitated management of alerts. Other clinicians involved in the care of patients with CIEDs, such as providers in other cardiology specialties, primary care providers, or emergency department physicians, may require another display of data with facilitated interpretation to help inform them of device status. CIEDs capture data that have important implications for clinical decision making across the trajectory of care, and it is essential that the information is presented in a way that is useful and interpretable for patients and their care team overall.

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Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.cvdhj.2022.10.007.

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