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04

Clinical EVIDENCE

CRT-D extended battery longevity and economic impact

Cost Savings Associated with Extended Battery Longevity in Cardiac Resynchronisation Therapy Defibrillators (CRT-D) (Williams et al.)[1]

A literature review supporting S-ICD as a valid alternative to TV-ICD

Ten years of subcutaneous defibrillator therapy: Consolidated clinical evidence and future perspectives (Magnani et al.)[2]

New data on pacing performance of the EMPOWER™

Pacing Performance of the First Leadless Pacemaker Communicating with an S-ICD from the full cohort of the MODULAR ATP study (Mont et al.)[3]

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Summary

This edition of Clinical Evidence offers an overview of extended CRT-D battery performance and benefit, provides an in-depth summary of the evidence supporting S-ICD journey and delve into the first data about the EMPOWER leadless pacemaker.

An economic analysis[1] confirms the significant cost-saving associated with the use of extended battery longevity (2.1Ah) in CRT-D devices. Moreover, data from HRS congress show that, among different manufacturers, Boston Scientific CRT-D devices have longer longevity. The second part of this edition is focused on a comprehensive review[2] of the state-of-the-art of the subcutaneous therapy, which is supported by decades of proven clinical evidence demonstrating its safety and efficacy. Throughout the journey of this therapy, significant technological innovations have emerged, leading to recent discussions about the pacing performance of EMPOWER leadless pacemaker[3], the first leadless pacemaker capable of offering a modular approach for S-ICD implanted patients.

Performance of CRT-D batteries and cost-saving associated to extended longevity

Cardiac Resynchronisation Therapy Defibrillator (CRT-D) replacements carry higher risks of complications, including infection[4], pocket-related surgical re-interventions[5], and hospitalisations, with the risk escalating with each subsequent replacement. Recent data show a 244% increase in costs when three replacements are performed compared to one[6], highlighting the significant clinical and economic burden associated with multiple replacements. In this paper, Williams *et al.*[1] estimate the potential cost savings associated with extended battery longevity in a cohort of Medicare[(a)] patients receiving an initial CRT-D implantation.

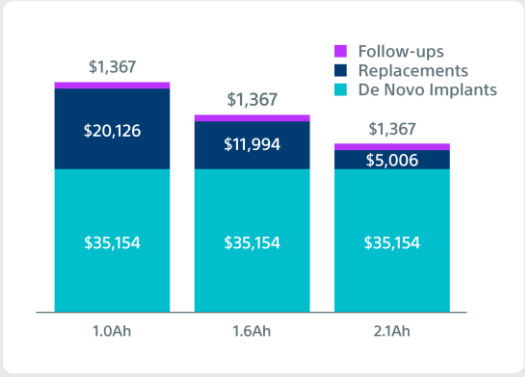
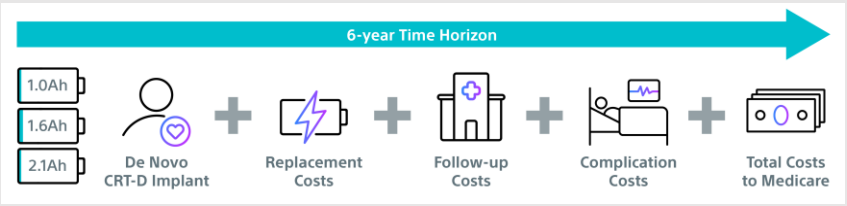


Figure 1: Medicare costs per patient over 6 years



An Excel-based economic model using a decision tree was developed to estimate cost savings over a 6-year period, exploring three battery capacities: 1.0 ampere-hours (Ah), 1.6Ah, and 2.1Ah.

Yearly risk of all-cause mortality, device-related complications, and battery depletion were estimated.

The average total costs to Medicare over 6 years were reported in Figure 1.

The costs of the initial implantation, related complications, and routine follow-up visits were the same across devices, thus, the differences in total average per person costs were driven by costs associated with replacements.

(a) Medicare patients and costs used in this analysis come from United States practice

$15,120 Cost saved* using 2.1Ah CRT-D vs. 1.0Ah CRT-D.

$6,988 Cost saved* using 2.1Ah CRT-D vs. 1.6Ah CRT-D.

**Per person over 6 years*

From HRS Congress 2024

During Heart Rhythm Society (HRS) Congress 2024 (Boston, 16-19 May), Freeman *et al.*[7] presented a poster about battery longevity performance: ***"Implantable cardioverter-defibrillator battery longevity variation by manufacturer and device type".***

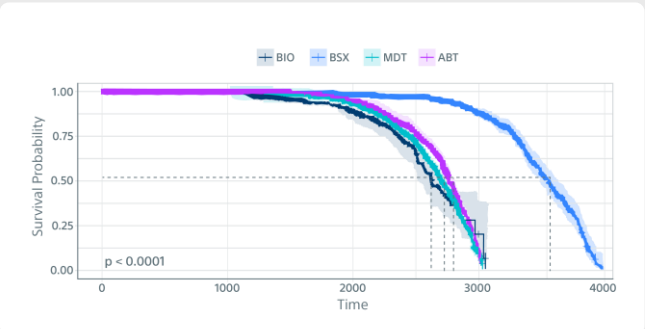


Figure 2: CRT-D Battery longevity among different manufacturers

17,247 biventricular ICDs were analysed and a substantial variation in battery longevity was observed among different manufacturers.

Boston Scientific (BSX) transvenous had the longest median battery longevity for CRT-D devices (Figure 2), **exceeding that of other manufacturers by more than 2 years:** BSX 3,364, Abbott (ABT) 2,527, Medtronic (MDT) 2,378, Biotronik (BIO) 2,311 days; ($p < 0.001$).

These findings persisted after adjusting for device parameters associated with battery longevity.

Boston Scientific transvenous devices had the longest median battery longevity, even for single and dual chamber models.

"Adequate consideration of the multiple factors affecting device choice, including the economic impact of generator replacement due to battery longevity, should be a consideration in physician decision making at the time of initial implant." [1]

Clinical Evolution of the S-ICD: From First Generation to the Future

A recent article published in the Journal of Cardiovascular Electrophysiology aimed to review the existing evidence supporting the subcutaneous ICD (S-ICD) as a valid alternative to the transvenous ICD (TV-ICD), highlighting the milestone achievements of this technology over the last decade and exploring future perspectives.[2]

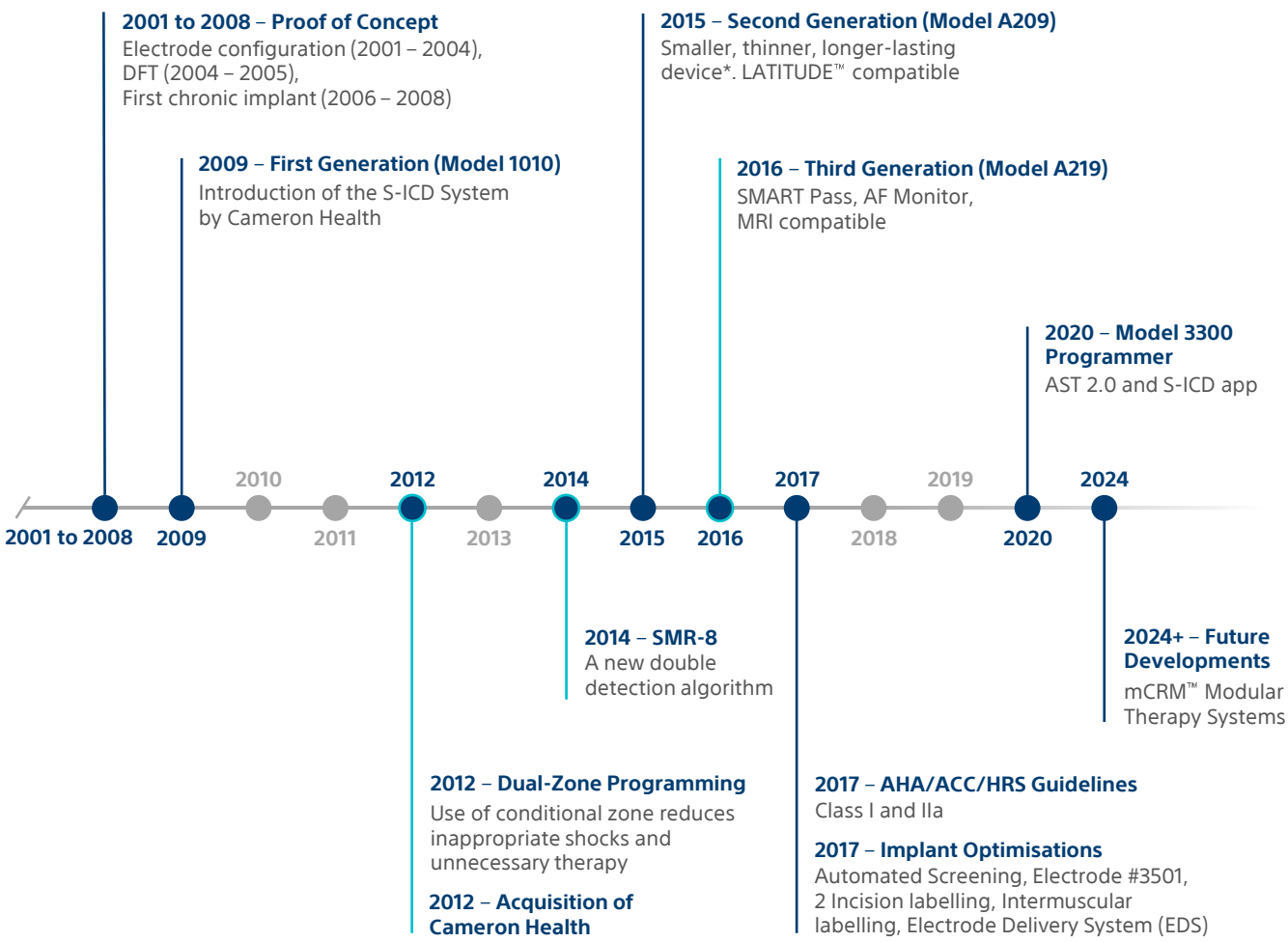
Since its introduction into clinical practice, the primary goals of the S-ICD have been to **avoid the disadvantages of vascular access** and to achieve high efficacy levels with a **significant reduction in complications and inappropriate shocks** (IAS).

After the commercial release of the S-ICD, several post-approval registries were conducted to document clinical outcomes in real-life settings.

	IDE	Effortless	Effortless Long term follow-up	PAS	PAS Long term follow-up	Praetorian	Untouched
Publication date	2013	2014	2022	2017	2023	2020	2021
Patients (n)	314	472	984	1637	1643	426	1116
Follow-up (months)	6	12	60	1	50	49	18
Mean age (years)	52+/-15	49+/-18	48+/-17	52+/-15	52+/-15	63	56+/-12
Mean ejection fraction (%)	32+/-14	42+/-19	43+/-18	32+/-14	32+/-14	30	26+/-6
S-ICD generation	I	1	1	1	1	2	2-3
Conversion rate (%)	100	98	98	98.7	98.4	N/A	98.4
Inappropriated shock (%)	13	7	16.9	0.2	15.8	9.7	4-2.4

Figure 3: Comparison of milestone studies on the S-ICD outcome

Developments over time have significantly reduced the IAS rate for S-ICD: improved patient screening, introduced new algorithms and filters into the device, and clinical practice has evolved to dual-zone programming and higher rate cut-offs to avoid unnecessary therapy.[2]



IDE[8] **(6 months)**
▶ **Efficacy rate: 100%** ▶ **Safety rate 92.1%**

EFFORTLESS[9] **(5 years)**
▶ **Efficacy rate: 98%** ▶ **0% Endocarditis**

PAS[10] **(≈ 4 years)**
▶ **Efficacy rate 98.4%** ▶ **Complication-free rate 96.2%**

PRAETORIAN[11] **(4 years)**
▶ **S-ICD non inferior to TV-ICD (Primary endpoint 15.1% vs 15.7%)**

UNTOUCHED[12] **(18 months)**
▶ **IAS rate (3rd generation): 2.4%**

Results

- Cumulative evidence has confirmed **the S-ICD as a viable alternative to conventional transvenous ICD (T-ICD)** systems, especially for patients with vascular access challenges or a heightened risk of infection.
- **Early-generation** S-ICDs have demonstrated reliable and consistent performance from the outset, proving their safety and effectiveness over time.
- While earlier studies predominantly included younger patients with higher ejection fractions (EF), more recent research indicates favourable outcomes in **patients with comorbidities** comparable to those typically considered for TV-ICD implantation.
- **Advancements in programming and technology** have further optimised S-ICD system performance. To keep up with the modern TV-ICD technology and anticipate patients' needs, several additional features have been introduced over time. Key enhancements include dual-zone programming, automatic QRS-T sensing analysis, the SMART Pass algorithm, MRI compatibility, and atrial fibrillation detection.
- Over time, the rate of **device-related complications** has progressively decreased due to the operators' learning curve and advancements in implantation techniques (intermuscular+ 2-incision technique).
- The risk of needing bradycardia, tachycardia, or resynchronisation pacing later on in patients who did not initially require such interventions appears to be negligible. However, if needed, exciting developments are currently underway about the potential synergy between leadless pacemakers and S-ICD systems.

A growing body of evidence has firmly established the S-ICD as a reliable alternative to traditional ICD systems. Moreover, recent studies indicate a promising opportunity to extend S-ICD indications to patient populations that were previously not deemed eligible, highlighting its broader applicability in clinical practice.

New data on pacing performance of the EMPOWER™

From ESC Congress 2024

The pivotal MODULAR ATP Trial[13] is a prospective, non-randomised, single arm, multicentre, pre-market, global trial which evaluated the safety, effectiveness, and performance of the Modular CRM (mCRM™) System.

In addition to evaluating the ability of the EMBLEM™ S-ICD to successfully communicate with the leadless pacemaker (EMPOWER LP) to deliver intracardiac ATP, the MODULAR ATP trial evaluated the pacing performance and effectiveness of the EMPOWER LP to function as a standalone VVIR pacemaker.

During the European Society of Cardiology (ESC) Congress 2024 (London, 30 Aug – 2 Sept), Mont *et al.*[3] presented new data about the pacing performance of the first leadless pacemaker communicating with an S-ICD, from the full cohort of the MODULAR ATP study.

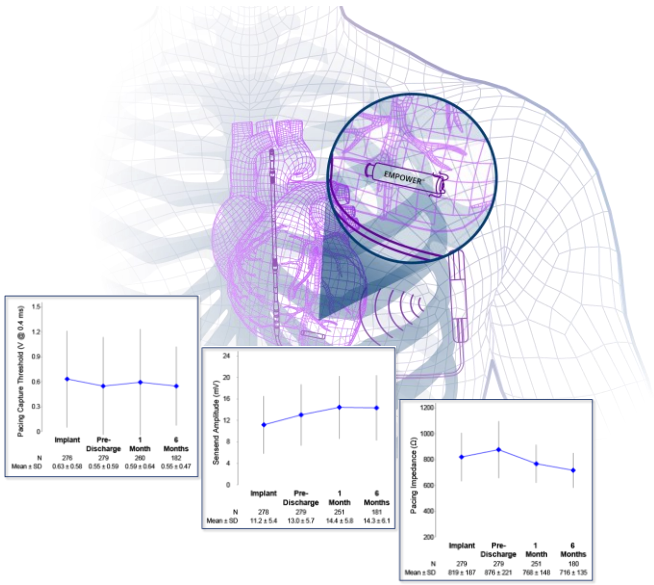


Figure 4: Pacing Capture Threshold, Sensed Amplitude and Pacing Impedance at implant and during follow-ups.

Results

- **All leadless pacemaker** (N = 280) were **successfully implanted.**
- The percentage of patients who were **free from leadless pacemaker–related major complications** was **97.5%.**
- At implant, pacing capture thresholds are notably low, 0.63 ± 0.58 (V) at 0.4 ms, while the R-wave amplitudes are high, 11.2 ± 5.4 (mV). Additionally, the impedance values are within acceptable ranges, ensuring optimal performance of the pacing system at implant and during follow-up.
- **None** of the patients requested **inactivation** of pacemaker therapy for any reason.
- **No** devices have been retrieved/abandoned due to **device failure.**
- In the **Holter sub-study**, pacing and sensing performance of EMPOWER LP were successfully validated during an overdrive pacing session (**no loss of capture**).
- The results of the **rate response sub-study** supported the use of the leadless pacemaker's accelerometer for VVIR pacing, with the slope of normalised sensor rate falling within the predefined endpoint range.

100% Implant Success — **All leadless pacemaker were successfully implanted.**

97.5% Safety — **Freedom from major pacemaker-related complications.**

0% Pacing Inactivation — **Therapy OFF.**

0% LOC — **Loss of Capture.**

0% Failure — **Device Failure.**

The MODULAR ATP trial demonstrated that The EMPOWER leadless pacemaker, the first ATP-capable leadless pacemaker, delivered safe and effective VVIR pacing.

"Battery longevity and its predictors in S-ICDs: A mathematical analysis derived from a large dataset"[14]

Van der Stuijt W. *et al.*

S-ICD device longevity is officially labelled at 7.3 years, under normal usage, including enabled features like remote monitoring and pre-arrhythmia EGM storage, for second- and third generation devices (EMBLEM™ and EMBLEM MRI™)[15] Van Der Stuijt *et al.* conducted an analysis to investigate the real-world longevity of S-ICD devices, recently published on Heart Rhythm Journal.[14]

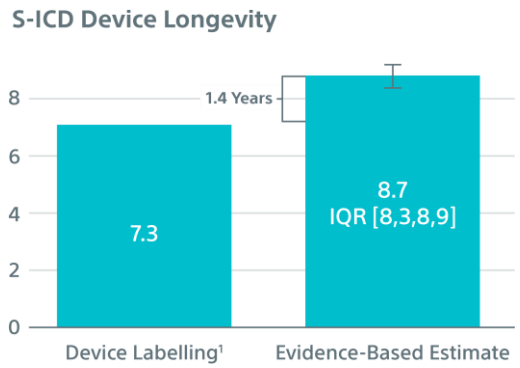
In November 2022, 32,678 de-identified data from US S-ICD devices in the LATITUDE™ monitoring system were analysed. A Monte Carlo simulation was used to estimate the remaining battery life, based on known relationships of current, remaining battery capacity (total capacity – capacity used), and estimating future high voltage events. Operational characteristics and device features were analysed through univariable and multivariable proportional hazard analyses.

Breaking News
Longevity for 32,678 EMBLEM devices averaged 8.7 years, exceeding the labelled 7.3 years.

What are the main findings?

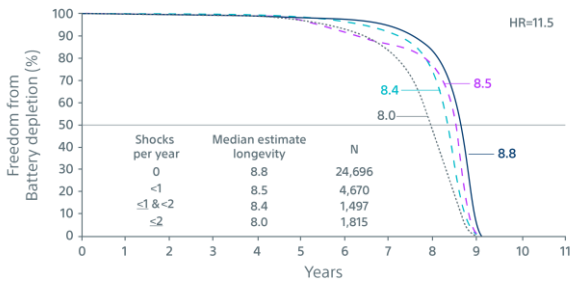
Real World Longevity

- **Longevity** for 32,678 EMBLEM devices averaged **8.7 years**, exceeding the labelled 7.3 years, despite 13,900 (42.5%) devices were under the Premature Battery Depletion (PBD) advisory.[16]



Factors Impacting Longevity

- The greatest impact on longevity was found to be **the number of spontaneous shocks experienced**, with patients experiencing ≥2 shocks/year having a 9.6 month longevity impact compared to patients with no spontaneous shocks.
- **No other factor impacted longevity** ≥ 1.1 months.



Longevity estimates derived from a large dataset have shown that device lifespan exceeds the labeled value. Additionally, the battery life is virtually unaffected by the activation of device features, such as Atrial Fibrillation Trend or the frequency of remote monitoring transmissions.

Key Messages

- **CRT-D extended battery longevity and economic impact:** The use of extended longevity CRT-D devices leads to substantial cost savings for Medicare by reducing healthcare costs due to replacement procedure and improving overall cost-effectiveness in patient care. These data indicates long-term economic considerations should be accounted for in device selection.[1]
- **A literature review supporting S-ICD as a valid alternative to TV-ICD:** The S-ICD has emerged as a valid and safe alternative to the TV-ICD, reinforced by a decade of consolidated clinical evidence and continuous technological advancements.[2]
- **New data on pacing performance of the EMPOWER™:** New data from MODULAR ATP Trial demonstrated safety and performance of the first ATP-capable leadless pacemaker.[3]

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