**APPENDIX A1: Maturity framework**

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| **1. Promotion of unique device identification (UDI):** The precise identification of medical devices is essential for evaluating the performance over time. Currently, most registries use manufacturer names, device names or billing codes for product identification, but this is mostly inadequate for unique product identification. Both regulators and MDEpiNet now advocate use of Unique Device Identification (UDI) system.[a] The FDA UDI rules require manufacturers to assign unique identifiers to their marketed devices and submit required device attributes to a UDI Database. In the U.S., the FDA's AccessGUDID, a public portal of the Global Unique Device Identification Database (GUDID), serves this purpose.[b] By providing a unique numeric or alphanumeric code for each device model and an identifier that includes the production information for that specific device (e.g., serial number, manufacturing date), the UDI delivers the most accurate way to identify and track medical devices. | | |
| Device Identification domain describes the registry's ability to uniquely identify a device. Ideally, the UDI would be included; however, when unavailable, the registry should capture a combination of identifiers that enables unique identification of the device (e.g., catalog number, manufacturer, brand or generic name, device description). | Level 1 *Early Learner* | The registry or a linkable database in a CRN is capturing device information that is available under CPT, ICD, or other generic coding for the device-based procedure. [i] |
| | Level 2 *Making Progress* | The registry or a linkable database in a CRN is capturing device information using at least manufacturer and specific device names and leverages relevant CPT, ICD, or other generic coding system. [i] |
| | Level 3 *Defined Path to Success* | Building from level 2 achievements, the CRN has conducted large scale demonstration project to include manufacturer's product catalog numbers or UDI that included at least five percent of annual patient enrollment. |
| | Level 4 *Well Managed* | The registry or a linkable database in a CRN is routinely capturing device information with manufacturer's product catalogue numbers or UDI that can identify devices and mapped to attributes/features needed for research and surveillance. |
| | Level 5 *Optimized* | The registry or a linkable database in a CRN is routinely capturing device information with UDI and mapping to attributes/features needed for research and surveillance. UDI information is seamlessly and efficiently integrated with the registry or CRN operations. |
| [i] Level 1 and level 2 achievements can be sufficient if only one device and few devices are on the market and if such coding would appropriately identify the device. In all other instances, catalog numbers and ideally UDIs are required. | | |

[a] Gross TP, Crowley J. Unique device identification in the service of public health. *The New England journal of medicine.* 2012;367(17):1583-1585.

[b] Unique Device Identification System. In: FDA, ed. *21 CFR § 16, 801, 803, 806, 810, 814, 820, 821, 822, 830.* Vol 0910-AG312013:58785-58828.

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| **2. Improving data collection efficiency:** Minimizing the burden of data collection processes is crucial, to maximize data submission. Centers with advanced informatics are able to organize their clinical workflows to record data needed for registries in ways that reduce effort and so improve the completeness of data collection.[c] This kind of structured data capture minimizes the number of staff needed for data collection and the time they need to spend. Agreements about the core vocabulary and corresponding technical (database) representation allow integration of high-quality data into the processes of care; promotion of automated collection; lowering the burden of data collection; minimization of human error; and reduction of resource requirements. Efforts to reduce the burden of data collection and improve the quality of data include scanned capture of UDI on device labels and auto-population of key device attributes from AccessGUDID. AccessGUDID offers means to auto-populate fields such as manufacturer, brand, device size, and other standard fields needed for analysis. Finally, soliciting patient input and collecting data through innovative patient-facing applications enables inclusion of endpoints of interest, addressing patient preferences and gaining further efficiencies in data collection. | | |
| Efficiency domain describes the extent to which the registry is embedded in the healthcare quality improvement system so that data collection occurs as part of care delivery (i.e., not overly burdensome, not highly complicated, not overly costly) and integrated with workflow of clinical teams. A key pre-condition for this domain is that the core minimum data process with key stakeholders is developed in order to define the CRF and the elements are clinically relevant and harmonized. This will ensure that reliable and relevant data elements with proper definitions are included in the data collection effort. | Level 1 *Early Learner* | Heavy burden of data collection with ad hoc data elements on a project basis but without agreement on clinically relevant core minimum data elements. |
| | Level 2 *Making Progress* | Clinically relevant core minimum data elements are established with key stakeholder input. Data collection is started but there is a heavy burden on data collectors (manual data entry with no automation). |
| | Level 3 *Defined Path to Success* | In addition to level 2 achievements, technologies are in place (e.g., structured data extraction from EHRs; mobile apps) to reduce burden on data collectors, and a pilot project is completed on adoption of data and terminology standards that will enable exchanges between data information ecosystems (interoperability). |
| | Level 4 *Well Managed* | Technologies are in place (e.g., structured data extraction from EHRs; mobile apps) to reduce burden on data collectors, and a multisite demonstration project is completed on adoption of data and terminology standards that will enable exchanges between data information ecosystems (interoperability). |
| | Level 5 *Optimized* | Technologies are in place (e.g., structured data extraction from EHRs; mobile apps) for all core minimum data elements and a fully automated data collection for most core minimum data elements, and there is a full adoption and integration of |

[c] Sanborn TA, Tcheng JE, Anderson HV, et al. ACC/AHA/SCAI 2014 health policy statement on structured reporting for the cardiac catheterization laboratory: a report of the American College of Cardiology Clinical Quality Committee. *J Am Coll Cardiol.* 2014;63(23):2591-2623.

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| | | data and terminology standard (assumes complete interoperability). |

| **3. Advancing data quality for regulatory decision-making:** A key tenet of the CRNs construct is the development and adoption of discipline-specific core minimum data in collaboration with regulators. This includes reaching agreement on precise definitions of data elements. Consecutive data collection and completeness (minimizing missing or out-of-range values) are important in producing robust medical device evidence and CRNs strive to achieve adequate enrollment with complete records of the target population. Coverage (i.e., regional, national, health system etc.) is another important quality measure; and adequate coverage of hospitals and community practices within the scope of the registry is important for evidence generalizability. | | |
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| Data Quality domain focuses on relevance, coverage (scale), completeness of patient enrollment and data elements (records) at both baseline and follow-up, and accuracy verified by periodic audits (ideally annually or at least every two years). These four concepts take into account the relevance and reliability concepts outlined in the real-world evidence guidance issued by the Center for Devices and Radiological Health at the FDA. A key pre-condition for this domain is that the registry core minimum data elements and research modules are defined in collaboration with key stakeholders. This will ensure relevance because data elements with proper definitions and key stakeholder input are included in the data collection efforts (see also | Level 1 *Early Learner* | The coverage includes the pilot registry/ CRN with single or several site efforts that capture small patient populations (data completeness and other quality measures are not yet relevant). |
| | Level 2 *Making Progress* | The coverage includes a large number of sites (large population) but mostly inadequate enrollment [ii] of patients but robust completeness [iii] of data elements (records). Plans are in place for conducting audits to assess and improve the data quality. |
| | Level 3 *Defined Path to Success* | The coverage includes a large number of sites engaged (large population), there is adequate enrollment [ii] of patients and completeness [iii] of data elements (records). Plans for conducting and executing audits of data quality at least once with minimum* requirements. |
| | Level 4 *Well Managed* | The coverage is at least regional or includes a large national health system with adequate enrollment [ii] of patients and completeness [iii] of data elements (records). Ongoing sequential audits with at least one audit completed with moderate* requirements. |
| | Level 5 *Optimized* | The coverage is national with adequate enrollment [ii] of patients and completeness [iii] of data elements (records). Initiating routine audits with extensive* requirements (at least bi-annual). |

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| TPLC domain). Coverage (scale) concept is related to extent of participation of sites that use particular a technology/device. Completeness concept is related to how complete the enrollment is at each site and the core minimum data (records). Accuracy is defined by the degree of matching of the CRN/registry data to the source documents. | *Auditing requirements: Minimum includes verification of at least exposure (e.g., device) and outcomes using a generalizable cohort; moderate includes verification of exposure (e.g., device), outcomes and key risk factors using a generalizable cohort; and extensive includes verification of entire data collection forms using a generalizable cohort. |
| [ii] Greater than 80% regional, national, or major health system coverage might be adequate; [iii] Greater than 80% enrollment with complete records might be adequate. | |

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| 4. **Considering Total Product Life Cycle (TPLC) research:** Generating evidence from the time of early adoption of technologies is an important priority to support attainment of startup funds. Registries for breakthrough technologies can be designed to include specific factors needed for evaluation of effectiveness (e.g., Transcatheter aortic valve replacement (TAVR)); and to facilitate later transformation into a quality registry, by ensuring collection of minimum core data fields necessary for surveillance. A key issue is to not confuse the purpose of the registry with specific investigations that should be 'nested' within it: the latter can include collection of additional data elements. Using RWE in clinical trials is feasible, particularly in 'pragmatic trials' where patients and device operators included are broadly representative of the target population. To evaluate long-term outcomes, mature CRNs need to demonstrate robust linkage with relevant data sources that enable enhancement of data and longitudinal follow-up. [d] [e] | | |
| TPLC domain describes the total life cycle of a device and the notion that registries can serve as the infrastructure for conducting both clinical research and device surveillance at different stages of device evaluation. Registry core minimum data elements and research modules should | Level 1 *Early Learner* | Developed a plan for conducting short-term or long-term clinical outcome studies (e.g., direct follow-up or data linkages) and surveillance. |
| | Level 2 *Making Progress* | Developed some capacity (e.g., IT infrastructure system) for conducting short-term or long-term clinical outcome studies and surveillance. |
| | Level 3 *Defined Path to Success* | Registry has experience with at least one short-term or long-term clinical study or surveillance during product lifecycle that assists regulatory decision making. However, it has limited capacity for analytics and burdensome/ |

[d] Columbo JA, Martinez-Camblor P, O'Malley AJ, et al. Long-term Reintervention After Endovascular Abdominal Aortic Aneurysm Repair. Ann Surg. 2019;July 8, 2019 - Volume Publish Ahead of Print - Issue - p.

[e] Columbo JA, Sedrakyan A, Mao J, et al. Claims-based surveillance for reintervention after endovascular aneurysm repair among non-Medicare patients. *J Vasc Surg.* 2019;70(3):741-747.

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| ensure relevance of the collected data from stakeholder perspective (see also Data Quality domain). In addition, the use of registries may allow for a seamless integration of evidence generation at the point of care throughout the device life cycle. A critical aspect of lifecycle research is obtaining long-term outcome data with efficient methodology. This domain is aligned with FDA's TPLC vision. | | inadequate [iv] process to obtain long-term outcome data (e.g., linking registry to EHRs or claims data) for research and surveillance. |
| | Level 4 *Well Managed* | Registry has experience with at least one study during the product lifecycle that assists regulatory decision making. Developed sustainable capacity for analytics and an adequate [iv] process to obtain long-term outcome data (e.g., linking registry to EHRs or claims data) for research and surveillance. |
| | Level 5 *Optimized* | Registry has substantial experience (e.g., three or more studies) that assisted regulatory decision making, has sustainable capacity for analytics, and an adequate [iv] process to obtain long-term outcome data (e.g., linking registry to EHRs or claims data) for research and surveillance. |
| [iv] If direct follow up is conducted, greater than 80% achievement might be adequate. When using data linkages, greater than 90% might be adequate. | | |

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| **5. Establishing governance and ensuring sustainability:** MDEpiNet emphasizes strong governance and sustainability as essential issues for the CRNs. Even if a CRN is mature in many domains, any registry that is solely funded as a pilot study or by a standalone manufacturer will cease to exist once the organization has achieved its short-term goals. Sustainability requires multiple stakeholders to buy into the value that is generated by the CRN. CRNs that are hosted by a professional society or health system, with multiple funding sources and transparent leadership and governance, are most likely to be sustainable in the long-term. MDEpiNet promotes creating a 'Steering Committee' as well as 'Research and Publication' and 'Sustainability' subcommittees to engage stakeholders and to create multiple leadership opportunities for dedicated and enthusiastic experts. Holding annual think-tanks or meetings with stakeholders helps to achieve alignment and priority setting for infrastructure and research. Creating an atmosphere of collaboration and developing trust will enrich a CRN and is key to establish and sustain the continuous dialogue in supporting a learning (healthcare) system of medical device evaluation. | | |
| <u>Governance and Sustainability</u> domain describes the governance structure focusing on participation of major stakeholders enabling generalizable (regionally, nationally or health system | Level 1 *Early Learner* | Absence of professional society/major health system/state endorsement, mostly pilot and project level governance. |
| | Level 2 *Making Progress* | Absence of professional society/major health system/state endorsement. Reasonable funding is available (e.g., support for a specific project at NIH R01 level or industry sponsorship at the same level). |

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| wide) data collection and transparent governance*. The hosting organizations include professional societies, integrated health systems, payers, and various states. In addition, the ability for the registry to obtain major and diverse sources of funding is critical for sustainability. Registries and CRNs built by manufacturers for their own purposes are special instances that are not in scope of this domain. | Level 3 *Defined Path to Success* | Hosted by a professional society/major health system/state. Reasonable funding is available (e.g., support for a specific project at NIH R01 level or industry sponsorship at the same level), establishing transparency in governance. |
| | Level 4 *Well Managed* | Hosted by a professional society/major health system/state. Robust funding is available (e.g., multi-year large scope projects funding in place at NIH center grant level or multiple industry sponsorship at the same level), and governance is transparent. |
| | Level 5 *Optimized* | Hosted by a major professional society/major health system, commitment to funding indefinitely (e.g., renewable NIH center grant level or multiple industry sponsorship at the same level), and governance is transparent. |
| *Transparent governance metrics include but are not limited to participation of major stakeholders and clear organizational structure with steering committee, subcommittees, and data access policies. | | |

**6. Leveraging registries as quality systems**: Most healthcare enterprises participate in registries as tools for quality improvement. Analyses of processes and outcomes from registries serve as feedback to inform the sites about conformance with guidelines, comparative patient outcomes, opportunities to improve care, and other critical strategic, administrative, and operational imperatives. Device use and outcomes are considered part of this function.[f] This infrastructure will enable medical device research and surveillance in the context of both the device and the device operator's performance. Lessons learned from cardiology, cardiac surgery and vascular surgery

[f] Sedrakyan A, Campbell B, Graves S, Cronenwett JL. Surgical registries for advancing quality and device surveillance. *Lancet (London, England).* 2016;388(10052):1358-1360.

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| registries can be very helpful for the evaluation and improvement of care.[g] [h] [i] [j] Sharing best practices in provider feedback, such as use of creative data visualization techniques, can enhance clinician and hospital participation in quality improvement registries. | | |
| Healthcare Quality Improvement domain describes the registry process for quality improvement. The registry is a healthcare delivery improvement system or is evolving into one as device technologies are diffused into practice and need continuing evaluation (including outlier identification). The registry has established mechanisms to bring about beneficial change in healthcare delivery through stakeholder participation, ownership, and integration into the relevant healthcare systems. | Level 1 *Early Learner* | Registry does not have provider feedback benchmarking process and conducts limited device outlier assessments. |
| | Level 2 *Making Progress* | Registry has more than one, and growing number of participants in provider feedback benchmarking process and conducts limited device outlier assessments. |
| | Level 3 *Defined Path to Success* | Registry has initiated routine provider feedback for all participating sites. As part of that process, it is developing routine device outlier assessment. |
| | Level 4 *Well Managed* | Registry has completed first major periodic feedback process. As part of the process, it has initiated device outlier assessment. |
| | Level 5 *Optimized* | Registry has regular and ongoing (at least annually or similar) provider feedback in place and routinely includes device outlier assessment. Ideally, there is automation of quality process with advanced analytics and visualization tools integrated with data collection. |

[g] Carroll JD, Edwards FH, Marinac-Dabic D, et al. The STS-ACC transcatheter valve therapy national registry: a new partnership and infrastructure for the introduction and surveillance of medical devices and therapies. *J Am Coll Cardiol.* 2013;62(11):1026-1034.

[h] Sedrakyan A, Campbell B, Graves S, Cronenwett JL. Surgical registries for advancing quality and device surveillance. *Lancet (London, England).* 2016;388(10052):1358-1360.

[i] Shahian DM, Grover FL, Prager RL, et al. The Society of Thoracic Surgeons voluntary public reporting initiative: the first 4 years. *Ann Surg.* 2015;262(3):526-535; discussion 533-525.

[j] De Martino RR, Hoel AW, Beck AW, et al. Participation in the Vascular Quality Initiative is associated with improved perioperative medication use, which is associated with longer patient survival. *J Vasc Surg.* 2015;61(4):1010-1019.

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| **7. Incorporation of *p*atient generated data and PROs:** Patient generated data and PRO collection is an important priority of the FDA and other regulators, for safety and efficacy in medical devices.[k] Patients can contribute is by serving as partners, participating in research and surveillance, and sharing their experience related to devices. Robust and comprehensive patient generated, and PRO data collection is possible when combined with use of mobile applications, advancement in EHR systems and linkages to EHRs and registries.[l] | | |
| The PRO measures should include collecting at least one general health and one disease-specific outcome measure. Center for Devices and Radiological Health at the FDA defines the PRO as a measurement based on a report that comes directly from the patient (i.e., study subject) about the status of a patient's health condition without amendment or interpretation of the patient's response by a clinician or anyone else. | *Level 1 Early Learner* | The CRN identified (ideally with patient engagement) and collaborated with stakeholders to define disease specific and general health validated PROs that meet regulatory guidelines. |
| | Level 2 *Making Progress* | In addition to level 1, the CRN conducted a demonstration project of obtaining PROs and integrating within CRN infrastructure. |
| | Level 3 *Defined Path to Success* | In addition to level 2, the CRN is able to seamlessly integrate PROs within CRN infrastructure using patient-facing applications. |
| | Level 4 *Well Managed* | In addition to level 3, the CRN is routinely obtaining PROs using a consecutive and generalizable sample and using these for research and surveillance and has conducted at least one study using PROs for a benefits and harms assessment of technologies. |
| | Level 5 *Optimized* | In addition to level 4, the CRN is routinely obtaining PROs on a large scale to allow benchmarking at the participating institutional level and has substantial experience of using PROs for a benefits and harms assessment of technologies. |

[k] Value and Use of Patient Reported Outcomes (PROs) in Assessing Effects of Medical Devices. CDRH Strategic Priorities 2016-2017. https://www.fda.gov/files/about%20fda/published/Value-and-Use-of-Patient-Reported-Outcomes-%28PROs%29-in-Assessing-Effects-of-Medical-Devices.pdf. Accessed 04/09/2021.

[l] Wu AW, Kharrazi H, Boulware LE, Snyder CF. Measure once, cut twice--adding patient-reported outcome measures to the electronic health record for comparative effectiveness research. *J Clin Epidemiol.* 2013;66(8 Suppl):S12-20.