Postmarket Surveillance for Drug-Eluting Coronary Stents
A Comprehensive Approach

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The development and introduction of new medical devices have radically changed the practice of medicine. No area of medicine has been affected more than cardiology, with new devices facilitating the effective treatment of coronary artery disease (percutaneous coronary interventions [PCIs]/stents), valvular heart disease (mechanical and bioprosthetic valves), and electrophysiological disorders (pacemakers and automatic implantable cardioverter-defibrillators). In addition to fueling the growth of the medical device industry, this explosion of technology has driven the development of new medical subspecialties, eg, interventional cardiology and electrophysiology. Other areas of medicine, including orthopedics and general surgery, have witnessed similar transformations. The current regulatory pathway for a significant-risk first-in-class medical device is typically a long, expensive, and risky process, culminating in a pivotal trial designed to demonstrate safety and efficacy. The pivotal trial phase is typically the most time-consuming and costly phase of the process. In the United States, medical devices are regulated by the Center for Devices and Radiological Health at the Food and Drug Administration (FDA), which has been charged by Congress to seek the “least burdensome means” when determining the scope of data required to evaluate the safety and efficacy necessary for device approval. Thus, pivotal trials by intention are designed to select patient cohorts most likely to demonstrate procedural benefit while limiting patient/study subject risk within the shortest time frame that can provide meaningful data. The realities of logistics, time, and resources limit the size and duration of most new device trials to 800 to 1500 patients, limiting the power of these trials to detect events with an occurrence rate of <1%. Furthermore, pivotal trials are conducted by the most experienced physician operators at medical centers with sufficient patient volume and research infrastructure to recruit and conduct clinical studies. Some have questioned whether results obtained under these settings from such narrowly defined patient subsets can be extrapolated to the “real-world” postapproval environment. In recognition of these limitations, it is frequently desirable to collect additional data on device performance after FDA approval for commercial release, ie, postmarket surveillance. The need for accurate, timely, and comprehensive postmarket surveillance has been highlighted by the recent introduction of drug-eluting stents into general clinical use.

The Second Dartmouth Device Development Symposium (3D2) held in October 2004 in Woodstock (Vt) brought together thought leaders from the major stakeholders in the medical device community, including clinical investigators, the FDA, large and small device manufacturers, and representatives from the financial community, to examine difficult issues confronting device development. Challenges surrounding postmarket surveillance of medical devices in general with a focus on interventional cardiovascular devices were examined and discussed. This article provides a summary discussion of the following pertinent issues: (1) postmarket surveillance issues associated with the recent market release of drug-eluting coronary stents, (2) an overview of currently available major mechanisms for postmarket data acquisition, and (3) potential new approaches to postmarket device surveillance.

Early Commercialization of Drug-Eluting Stents: A Case Study

The strengths and weaknesses of currently available means to evaluate the performance of a medical device after FDA approval can be better understood by studying the recent market releases of the Cypher sirolimus-eluting coronary stent (Cordis/Johnson & Johnson) and the Taxus paclitaxel-eluting coronary stent systems (Boston Scientific).

Subacute Thrombosis and the Cypher Drug-Eluting Stent

The market introduction of the Cypher sirolimus-eluting coronary stent (Cypher Stent) was one of the most financially
successful in the history of the medical device industry. The US Cypher market release was the result of a multiyear development program costing Cordis/Johnson & Johnson more than $100 million dollars. Excitement over the Cypher stent was initially sparked by results from the small, 30-patient, single-arm first-in-man study that evaluated Cypher stent deployment in stable patients with simple coronary stenoses. Angiograms obtained 6 months after stent implantation showed a 0% incidence of binary restenosis rate.4 These first-in-man results were followed by 2 well-designed prospective, randomized, controlled trials: the Randomized Study With the Sirolimus-Coated BxVelocity Balloon-Expandable Stent in the Treatment of Patients With De Novo Native Coronary Artery Lesions (RAVEL) and the Sirolimus-Eluting Stents Versus Standard Stents in Patients With Stenosis in the Native Coronary Artery Study (SIRIUS). Target vessel failure (composite occurrence of death, myocardial infarction, and target vessel revascularization) was reduced by 68% (RAVEL) and 83% (SIRIUS) in Cypher-treated patients compared with the bare-metal stent comparator group.5,6 Thrombosis (subacute or delayed) was observed infrequently in these studies (subacute thrombosis in 1 of 653 Cypher-treated patients compared with 1 in 643 control subjects receiving bare-metal stents, late thrombosis in 2 of 653 Cypher patients and 3 of 643 bare metal control subjects). These studies were underpowered to evaluate any differences. It is important to note that these studies were performed at centers with highly experienced operators with the infrastructure necessary to participate in such a trial. Furthermore, the patient population in these studies was highly selected (clinically stable) with straightforward lesions. Review of one of our personal series (A.V.K.) indicates that <20% of cases performed during 2004 would have met these clinical and angiographic selection criteria. In April 2003, on the basis of data from 1296 patients enrolled in these studies (Cypher, 653; bare metal, 643), the Cypher stent was approved for treatment of discrete de novo coronary lesions.7

On the basis of the strength of the clinical data, coupled with the successful marketing by Cordis/Johnson & Johnson, the Cypher stent was rapidly adopted and accounted for roughly half of the 800 000 annual stent implantations in the United States.8 Within the first 75 days of marketing of the Cypher stent, the FDA, through its Medical Device Reporting (MDR) system, began receiving adverse event reports of stent thrombosis. By the end of the following month, additional information from Cordis’ own clinical trial data, along with an FDA review of comparable data on bare-metal stents, led the FDA to conclude, in another Web notification, that there did not appear to be a higher frequency of subacute thrombosis with Cypher stents than with bare-metal stents.11 Concomitantly, data from single-center experiences suggested that the incidence of Cypher stent thrombosis was roughly 1% and not different from either prior randomized clinical trial data or data collected after bare-metal stent deployment.12,13 It is important to note that these reports were focused primarily on events occurring typically within the first 30 days after implantation and do not reflect late thrombosis rates. Further observation noted, not surprisingly, that a likely contributing factor to the apparent increase in stent thrombosis reporting was the publicity associated with the Cypher launch and the company and FDA announcements that underscored the importance of adverse event reporting. The FDA issued an additional Web notification in October 2004 that included these observations and softened earlier warnings of increased thrombosis associated with the Cypher stent.14 Thus, from the first FDA notification on October 2003, almost 1 year elapsed before the FDA issued a conclusive statement that “the Cypher stent remains a safe and effective device when used according to the labeling, particularly with regard to patient selection and appropriate periprocedural medications.” In the context that nearly 3000 Cypher stents were being deployed daily during that time frame on a worldwide basis, a more accurate postmarket surveillance process could have provided valuable insight into the true incidence of stent thrombosis and the relationship of off-label use to its occurrence.

**Nondeflation of the Taxus Stent Delivery Catheter Balloon**

The Taxus paclitaxel-eluting coronary stent system (Taxus stent; Boston Scientific) was released in March 2004 and became the second drug-eluting stent commercialized in the United States.15 Similar to the Cypher stent, the market release of the Taxus stent was an extraordinary success, with
Careful inspection of retrieved failed units and comparison of these units with unused product (from both the same and different lots) allowed the company to quickly identify a subtle manufacturing flaw. Working in conjunction with the FDA, Boston Scientific Inc voluntarily recalled Taxus stents from lots identified as the source of the nondeflation events. All recalled stents were replaced with stents manufactured with a modified process. After reintroduction, there were 2 reports of possible nondeflation (with no associated clinical complication), during which time 105,000 stents were shipped, indicating that the instituted manufacturing changes had adequately rectified the problem. During this time, the Taxus stent/delivery system was also experiencing difficulties with “stickiness,” ie, difficult removal of the stent delivery balloon after stent deployment. Although distinct from nondeflation, retrieval difficulties resulting from stickiness have contributed to confusion about this issue. The Taxus recall received much attention from the public news media, which unfortunately failed to accurately identify the fact that 200,000 patients had undergone an uneventful deployment of this product.

Both the Taxus nondeflation and Cypher thrombosis episodes illustrate the strengths and weaknesses of the current postmarket surveillance systems. In the case of thrombosis (subacute and delayed) associated with drug-eluting stents, the ability to adequately characterize these events continues to be problematic. Until a more accurate understanding of stent thrombosis rates evolves, it will not be possible to develop or evaluate meaningful strategies aimed at significantly reducing the occurrence of this catastrophic event. In contrast, the current reporting system, coupled with established tracking methods (ie, identifying associated lots), allowed quick characterization of Taxus nondeflation events from which potential solutions could be rapidly developed and implemented. This observation may reflect inherent differences in the types of adverse events encountered. Nondeflation is a rare but serious problem linked temporally and physically to the device delivery system; as such, this profile facilitated precise event-device linkage. Because of a number of factors, stent thrombosis (subacute or delayed), although similar in seriousness to nondeflation, has been far more difficult to characterize. These factors include the relatively low frequency of this event, specific stent/stent delivery balloon issues (design and manufacturing), implantation technique (eg, stent-arterial wall apposition), and the specific pathobiology and pathoanatomy of the treated lesion. The problem is further complicated by time delay between implantation and clinical event. Finally, the clinical manifestations of stent thrombosis, eg, ST-elevation myocardial infarction, non–ST-elevation myocardial infarction, and recurrent angina, are not specific to stent thrombosis and are associated with events occurring at other sites within the coronary vasculature. Considering the fact that >1 million drug-eluting stents may be implanted each year, even a 1% to 2% serious adverse event rate would affect 10 to 20,000 patients at a minimum. The studies used to support the approval of the Cypher stent, the SIRIUS and RAVEL trials (total of 1296 randomized patients), were underpowered to detect differences in events occurring in ≈1% of patients. More than 13,000 randomized patients would have been required to provide a study with adequate statistical power to detect a 50% reduction in thrombosis rates occurring in 1% of patients (α=0.05 [2 sided]; power=0.90). Thus, a more robust method of postmarket surveillance seems to be needed.

Current Approaches to Postmarket Surveillance

Obtaining high-quality data that would provide a nuanced understanding of patient selection, device performance, and clinical outcomes in a broad-based patient population is both difficult and costly. Current sources of nationwide data from which one can obtain an understanding of device use after FDA approval include the MDR system, claims-made databases, and device databases/registries (general or specific). Each of these approaches has strengths and weaknesses for providing insights into various different aspects of real-world device use and performance. When these systems are evaluated, it is useful to consider the number of patients included and the detail of data collected as a continuum (the Figure). On 1 extreme are premarket pivotal trials (upper left quadrant), which may be contrasted with the postmarket MDR system (lower right quadrant). Premarket pivotal trials are centrally coordinated studies performed at premiere institutions with dedicated resources (research nurses) to carefully screen and follow patients in a prospectively defined manner over a circumscribed period of time. Conversely, the MDR system provides limited data on a large, unselected population.


MDR System

The medical device industry is subject to federal regulations focused on the evaluation, manufacture, marketing, and monitoring of devices. Currently, the nationwide postmarket safety and performance of a device are monitored primarily by the MDR system (and related initiatives such as the Medical Product Surveillance Network). The MDR system relies on manufacturers, importers, and user facilities to comply with mandatory reporting requirements. Manufacturers account for roughly 95% of the >150,000 reports submitted annually.

Although the MDR system is an easy-to-access and relatively inexpensive means for monitoring an entire device-treated population, particularly for rare adverse events, several weaknesses exist. First, consistent and complete event identification and reporting (completeness of ascertainment) are problematic because the system relies on the recognition of a complication, on the linkage of the complication to the suspect device, and finally on the understanding that a specific event requires reporting. Event reporting is dependent on each of these steps. Underreporting of events is well known and, depending on the device and outcome of interest, may be quite significant. Furthermore, a negative reporting bias may exist for both doctors and hospitals to report complications. Second, the system does not provide an adequate characterization (number, demographics, clinical situation, etc) of the patient population at risk (treated denominator) or the ability to meaningfully evaluate reporting patterns for potential biases. Currently, the treated denominator is poorly defined and described only in general terms on the basis of manufacturer sales and surrogate use estimates (eg, numbers manufactured or distributed). Third, the current system provides incomplete and inconsistent data (poor data quality) that are difficult, if not impossible, to validate through review of primary data sources, ie, medical records, angiography, ultrasonography, and MRI and CT scans. Consistent data validated by review of primary sources are essential to discern whether the adverse event reported truly is related to the device used (versus other devices or the natural history of the disease being treated) or whether other extenuating circumstances may have contributed (eg, complex bifurcation stenting, incomplete stent expansion, operator error, discontinuation of thienopyridines, and patient comorbidities).

Claims-Based Data From a Third Party

Another approach to postmarket surveillance is analysis of claims-based data drawn from a third-party payer, eg, Medicare or private insurers. Federal agencies and private payers, along with hospitals, have developed an extensive billing system based on diagnosis-related groupings and procedures. This system is governed by federal regulations that are subject to audits and enforced by both civil and criminal penalties. As a result, these data banks contain accurate records with specific information about admission diagnoses and procedures. When the Cypher stent was released into clinical practice, a specific diagnosis-related groupings code was already established that provided a means for identifying patients who received a drug-eluting versus a bare-metal stent. Once the stent type is identified, further database queries can discern the occurrence of subsequent hospitalizations or repeated interventions that might signal stent thrombosis or restenosis. This system removes many of the reporting biases that limit the value of registries (see below) and the MDR system. These strengths must be balanced by understanding that this system was not developed for accurate postmarket surveillance and thus provides data that may not be related to the performance of a specific device. Using this approach to evaluate the impact of drug-eluting stents on subacute stent thrombosis rates requires the use of a surrogate for stent thrombosis such as rehospitalization for acute myocardial infarction, repeated catheterization, and/or intervention. Such surrogates are intrinsically limited because acute myocardial infarction or repeated coronary intervention may occur for reasons other than subacute stent thrombosis; eg, repeated intervention may be done for planned, “staged” procedures or new coronary obstruction. Furthermore, this approach does not provide adequate data from which to discern operator/procedural behavior and selection bias, eg, limitation in drug-eluting stent availability for vessels <2.5 mm in diameter. Further limitations are related to the delay in which claims-based data are made available and the inability to review primary source data (without violation of HIPPA guidelines). The claims data also typically do not distinguish between the “same” products made by different manufacturers, thus making comparisons, if desirable, very difficult. Finally, gaps in coverage must be taken into account when longer-term outcomes are assessed. However, the combination of claims analysis and review of a randomly selected sample of medical records may establish the true frequency of an event being studied with greater accuracy than is currently possible.

Regional Databases

Regional databases provide an important means for obtaining insights into the impact of a specific technology on clinical outcomes after PCI. One example is the Northern New England Consortium, which includes all interventional cardiology and cardiac surgical programs in Maine, New Hampshire, and Vermont, that enter data using standardized research forms. Statewide databases that provide information similar to that in regional registries include New York, Washington, and Michigan. These databases allow follow-up of in-hospital complications, including rehospitalization, and survival in a large population, with minimal selection bias. Although these sources of information provide real-world understanding of both complications and survivability, they are not structured to follow outcomes associated with a specific device.

Multicenter Registries

A number of multicenter registries examine practice patterns and outcomes of procedures performed in the cardiac catheterization laboratory. The oldest and best known of these are the National Heart, Lung and Blood Institute Registry and the companion Dynamic Registry, which provide baseline features and in-hospital and 1-year outcomes on consecutive patients who underwent PCIs at large referral centers.
registries have provided the intervention community with important insights into the natural history of coronary artery diseases after PCI from both the present and stent eras. Registries such as these, however, are not structured to provide device-specific information. Furthermore, the ability of these registries to provide device-specific information is limited by their relatively small size (<3000 patients) and by the generalizability of data generated at large referral centers with highly experienced operators.26

In an effort to provide a global understanding of practices in the cardiac catheterization laboratory, the American College of Cardiology has funded the National Cardiovascular Data Registry (ACC-NCDR). The ACC-NCDR is a large multicenter database in which both clinical and procedural data and adverse events occurring up to hospital discharge are collected through the use of a standard set of 143 data elements. Data sets from each clinical site are transmitted quarterly to a central center for quality control and data analysis. The ACC-NDR has reported on the evaluation of a larger number of procedures (>125 000) from a wide spectrum of clinical sites (>130), providing important insights into real-world but short-term outcomes after PCI procedures. Despite the strength of the ACC-NCDR, these data are limited with respect to postmarket surveillance in that this database is not designed to track specific devices. Furthermore, data from nearly one third of the cases are excluded by quality-control screening, introducing by definition a poorly understood selection bias.27

Device-Specific Registries

A number of device-specific registries have been established voluntarily by manufacturers as part of their postmarket surveillance programs.28,29 In addition, manufacturers may meet the requirements for a postapproval study mandated by the FDA, as a condition of its approval of the device, by establishing a registry. With regard to mandated approaches, the device-specific registries may use the preapproval clinical pivotal trial machinery and thus expand the number of subjects and reduce the level of data detail collected. These registries can provide a consistent data set, which an independent events adjudication committee may audit using source documentation. Without such provisions, it is not possible to accurately discern the relationship between an event and a specific device in the presence of contributory clinical or coronary anatomic considerations. These registries strive to be representative of real-world use in incorporating low-, medium-, and high-volume implanting institutions that are geographically diverse. The commitment and resources to support the infrastructure required for such registries will likely limit participation to elite centers, large and small, that may not be reflective of clinical practice at other sites. In addition, operators may be reluctant to include cases with ambiguous indications or those at higher risk for complications. Finally, as with all studies, a “Hawthorne effect” may affect practice patterns with a consequent impact on clinical outcomes.30 Although the number of patients evaluated in these registries typically is larger than in the usual pivotal trial, it remains well below the ≥5000 patients required to detect and quantify a 1-in-200 adverse event frequency with adequate statistical power. Despite these limitations, registries are important because they provide important insights into device performance.

To overcome some of these issues, Web-based strategies have been developed to allow studies to include larger number of centers and patients. The e-CYPHER Registry is the largest single-device multinational postmarketing surveillance registry designed to evaluate safety and reliability of Cypher stents when used routinely outside the context of a clinical trial in a wide spectrum of centers throughout the world. This Internet-based study plans to enroll 15 000 patients from >400 sites worldwide, providing data on all patients receiving >1 Cypher stent with 1-, 6-, and 12-month clinical follow-up.31 Although this study will provide important insights into how Cypher stents are used outside the confines of a clinical trial, the exclusion of patient receiving other stents (bare metal and drug eluting) will diminish the ability to understand the entire spectrum of clinical practice.

New Approaches

As discussed above, limitations exist at both extremes of the postmarket surveillance landscape. Nationwide MDR passive surveillance, insurance claims-made data, and small industry-sponsored registries do not meet the criteria for a robust postmarket surveillance system. In conceptualizing the optimal postmarket surveillance system, we proposed the following minimal criteria.

• Assignation of device-related complications. An effective system should be able to identify specific devices (at least to the manufacturer level) and distinguish true device-related complications from spontaneous events related to disease natural history (eg, was the myocardial infarction 8 months after implantation of a drug-eluting stent a result of late stent thrombosis or progression of coronary atherosclerosis at another site?).

• Sample the entire population. An effective system should be able to sample outcomes throughout the known exposed population and thus provide an estimate of the frequency and association of a specific device-related complication.

• Establish a frequency threshold. The system should be adequately sensitive to monitor device-associated complications that occur at rates of 1 per 1000 for commonly used devices, eg, coronary stents. There is little benefit, beyond the currently existing MDR system, for detecting device-related adverse events that occur with frequencies of <1 in 10 000 uses (a 1-in-100 000 event with a stent device would effect 40 patients each year within the United States).

During the course of the 3D2 workshop, an alternative system was proposed that would link existing systems and provide a more definitive and nuanced understanding of real-world device usage and related complications than is currently available. Specifically, this system affords the ability to link existing “front-end” data obtained at the time of the procedure with “back-end” data derived primarily from Medicare and/or large third-party claims data.
Front-end data could be acquired by accessing per-procedure information already prospectively collected in each catheterization laboratory as part of the patient record for both billing and quality assurance purposes. Such data acquisition forms currently exist for monitoring PCI procedures, eg, ACC/NDR-compliant data forms, although a means to add device-specific identifier is required. Similar forms could be adopted for other devices such as pacemakers, defibrillators, and peripheral vascular stents. Because device-specific data (eg, manufacturer, model, length, diameter, lot number) for an implant such as a drug-eluting stent are captured within the patient record, this information can be gleaned during chart review. Clearly, more efficient ways to link unique patient identifiers with unique device identifiers are needed to evaluate the impact of device-specific differences in outcomes.

Changes in the standard patient consent form may be required to permit data collection, access to data files, and source documentation. Additional information could be accessed to address questions raised by analyses of back-end data (see below).

Back-end data would be obtained from large claims-made data banks (eg, Medicare and private insurers) with queries at specific time intervals, eg, 1 month, 6 months, 1 year, or after any front-end recorded entry. This could be supplemented by searching the National Death Index and by site-specific or central telephone follow-up (again covered by the entry consent form). In addition, this system would allow random selection of patients for review of source clinical data, eg, deidentified medical records, angiographic studies, and pathology, as well as telephone follow-up.

Once the front-end and back-end systems are largely in place, the main investment would be to establish front-to-back linkage functions. Individual back-end claims, once detected, would be entered into the linkage system and thus would provide the means to examine subsequent event rates in specific, well-circumscribed populations by device used or other demographic, clinical, and procedural determinants. Central to the utility of such a system is the ability to collect additional source data on each patient who experienced an adverse event under investigation. Such higher-level data collection would likely be performed on only a minority of randomly selected patients (eg, 10%) who experience subsequent events and a randomly identified group for comparison. Moreover, the linkage function could provide source data for end-point adjudication to determine whether an event (acute, early, or late) was definitely related, possibly related, or unrelated to the device(s) used in the index procedure.

The main differences between current and proposed options include the following:

- Accurate denominator determination and limited additional clinical information collection by use of existing data collection sources.
- Complete end-point detection by use of both claims-based and possibly site or central telephone follow-up.
- Access to both baseline and follow-up event source data.
- Adjudication of low-frequency device-related events.
- The potential to provide sensitive, timely, and fully adjudicated monitoring of postmarket adverse event rates.

Several obstacles must be overcome before such a system could be implemented. Costs for additional front-end data collection or telephone follow-up, as well as data processing and adjudication, must be borne by a governmental agency (Centers for Medicare & Medicaid Services [CMS], Food and Drug Administration [FDA], Agency for Healthcare Research and Quality [AHRQ], and National Institutes of Health [NIH]), private payers, industry (via per-device user fees/membership/trade group), or a combination of these resources. Clearly, such a system must represent a collaborative effort and include representation from clinician investigators, medical device manufacturers, regulators, professional organizations, and payers (public and private). This system must be structured in a manner consistent with local Institutional Review Board and national HIPPA guidelines to remove any participation bias. Furthermore, it is unclear whether the linkage function and data ownership should reside within a governmental agency, a professional society (eg, SCAI, ACC, AHA), industry, a third-party payer structure, or a not-for-profit private organization (eg, CRO). Specifically, any data analysis beyond the reporting of adjudicated and denominated device-specific adverse events (and publication or reporting thereof) would require clearance through an interdisciplinary committee representing the diverse participating interests. In terms of complete patient entry, smaller clinical sites may not have the infrastructure in place (or the resources) to participate in the front-end activity; thus, appropriate incentives for participating sites (whether voluntary and compensated or mandatory) would need to be developed. In addition, the ability to assemble an adjudication committee with an appropriate number of readily available disinterested senior clinicians also will be a challenge.

Furthermore, the system would not track all events (eg, subclinical late struts fractures) and thus would continue to rely on existing methods as appropriate. In fact, for devices in more limited clinical use (eg, humanitarian use devices) or somewhat broader use already covered by other approaches (eg, a prospective industry-sponsored registry), the proposed system may well prove to be redundant.

With these caveats acknowledged, a more comprehensive postmarket surveillance system such as the one proposed is required to ensure that our knowledge base keeps pace with the introduction of new technologies and allows their safe and effective use. Without such a system, we will continue to be ineffective in our ability to track, understand, and prevent infrequent but serious adverse events from high-use devices.

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References


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