**Key Considerations in Using Real-World Evidence to Support Drug Development**

**(Draft for Public Review)**

**Center for Drug Evaluation, NMPA**

**May, 2019**

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**Key Considerations in Using Real-World Evidence to Support Drug Development**

1. **INTRODUCTION**
2. Background and Purpose

Randomized Controlled Trials (RCTs) are considered the "gold standard" for evaluating drug efficacy and are widely used in clinical trials. With strictly controlled trial eligibility criteria and the utilization of randomization, RCTs minimize the impact of factors that potentially affect the causal inference, and hence result in more definitive conclusions and derive more reliable evidence. However, RCTs also have limitations: stringent entry criteria may reduce the representativeness of the trial population to the target population, the standard trial interventions used may not be completely consistent with real world clinical practice, the limited sample size and short follow-up time leads to insufficient evaluation of rare adverse events. These limitations bring challenges when extrapolating the RCT conclusions to real world clinical practice. In addition, for some rare and major life-threatening diseases that lack effective treatments, conventional RCTs may be difficult to implement, require substantial time costs, or raise ethical issues. Therefore, how to use real-world evidence (RWE) during drug R&D, especially as complementary evidence to RCTs in evaluating the efficacy and safety of drugs, has become a common and challenging question for global regulatory agencies, the pharmaceutical industry and academia.

First, we need to clarify the definition and scope of real-world evidence on a conceptual level.

Secondly, can and how will real-world data (RWD), as the fundamental basis of real-world evidence, provide sufficient support will face many questions that need to be discussed, including data sources, data standards, data quality, data sharing mechanism, data infrastructure and so on.

Third, the lack of regulatory guidance. At present, there are no mature and relevant regulations worldwide. Without sufficient experience, how to formulate guidelines that fit the reality of China's pharmaceutical industry requires active exploration and innovation.

Fourth, the methodologies for evaluating real-world evidence needs to be streamlined. Real-world evidence stems from the correct and adequate analysis of real-world data. The analysis methods used are mainly for causal inference, which often requires more complex models and assumptions, screening of corresponding covariates, identification of confounding factors, definition of intermediate variables and instrumental variables, etc., All these will put forward higher requirements for statistical analysts as well as the urgent needs for regulatory guidelines.

Fifth, the scope of real-world evidence application remains to be determined. The main role of real-world evidence is to complement, instead of substitute, the evidence provided by conventional clinical trials, and to form a complete and rigorous chain of evidence to further improve the efficiency and scientific validity of drug development. Therefore, it is necessary to clearly define the scope of application of real-world evidence according to the stage of drug development, and in the meanwhile adopt appropriate adjustment as the actual conditions evolve over time.

In light of the above, this guideline aims to provide clarity on the definition of real-world research, outline the use and scope of real-world evidence in drug R&D, explore the basic principles for the evaluation of real-world evidence, and consequently provide scientific and practical guidance for the industry to consider when utilizing real-world evidence to support drug development.

1. Progress in the development of related regulations or guidelines by domestic and foreign regulatory agencies

In February 2009, the American Recovery and Reinfection Act played a significant role in promoting Comparative Effectiveness Research (CER). Accordingly, the concept of real-world research (RWR, or real-world study RWS) was proposed given the context of the real world environment of CER.

In December 2016, the United States passed the 21st Century Cures Act (the Act), encouraging the Food and Drug Administration (FDA) to accelerate the development of pharmaceutical products by conducting research in the use of real-world evidence. Under the support of the Act, during 2017-2018 the FDA issued a series of guidelines, namely "Use of Real World Evidence to Support Medical Device Regulatory Decisions", "Guidelines for the Use of Electronic Health Record Data in Clinical Research" and "Framework for Real World Evidence Solutions".

In 2013, the European Medicines Agency (EMA) released the "Qualification opinion of a novel data driven model of disease progression and trial evaluation in mild and moderate Alzheimer’s disease", discussing the technical details in using real-world observational data to establish disease progression models. In 2014, EMA also launched the Adaptive Licensing Pilot to assess the feasibility of using observational study data to assist decision-making. Later in 2016, the “Scientific Guidance on Post-authorisation Efficacy Studies” was released.

At the International Council for Harmonisation of Technical Requirements for Medicinal Products for Human Use (ICH), Japan’s Pharmaceuticals and Medical Devices Agency (PMDA), proposed a strategic approach for pharmacoepidemiology studies submitted to regulatory agencies to advance more effective utilization of real-world data.

The systematic use of real-world evidence to support drug development and regulatory decision-making in China is still under development. However, the national drug regulatory agencies have already begun to utilize real-world evidence in the review practices. For example, the extended Bevacizumab treatment regimen in combination with platinum-based chemotherapies was approved in 2018, using real-world evidence from three retrospective studies. In another case, a drug was further evaluated, after marketing, through a prospective, observational real-world study to provide additional evidence on efficacy and safety.

1. **Relevant Definitions of Real-World Research**

Generally speaking, real-world research includes both research on natural populations and on clinical populations; the latter yields real-world evidence that can be used both to support medical product development and regulatory decisions, as well as for other scientific purposes. For that reason, this guidance focuses on real-world research that supports healthcare product development and regulatory decisions (see figure below).



Figure 1 The path from RWD to RWE, which supports regulatory decisions for medical products

We define real-world research as: collecting patient-related data in a real-world environment (real-world data), and obtaining clinical evidence (real-world evidence) of the value and potential benefits or risks of the medical products through analysis. The primary research type is observational, but it can also be pragmatic clinical trials.

1. Real-World Data
2. Definition

Section 505F (b) of the Federal Food, Drug, and Cosmetics Act (FD&C Act) defines real-world data as "data regarding the usage, or the potential benefits or risks, of a drug derived from sources other than traditional clinical trials". In “Framework for FDA’s Real-World Evidence Program” and the “Use of Real World Evidence to Support Medical Device Regulatory Decisions.", the FDA defines real-world data as "data relating to patient health status and/or the delivery of health care routinely collected from a variety of sources”. For example, Electronic Health Record (EHR) data, Electronic Medical Record (EMR) data, medical insurance data, product and disease registry data, patient report data (including home environment), and other health tests (such as mobile devices) data.

We define real world data as: data collected from patients’ medications and health status, and/or derived from various daily medical processes.

1. Source of real-world data

Common sources of real-world data in China include:

1) Health Information System (HIS): similar to EMR/HER, digital patient records including structured and unstructured data fields, such as patient demographics, clinical characteristics, diagnosis, treatment, laboratory tests, safety and clinical outcomes.

2) Medicare system: structured data such as basic patient information, medical service utilization, prescriptions, billing, medical claims, and planned health care.

3) Disease Registry System: a database of patients with specific (usually chronic) diseases, often derived from a cohort registry of the disease population in the hospital.

4) China ADR Sentinel Surveillance Alliance (CASSA): the use of electronic data from medical institutions to establish an active monitoring and evaluation system for the safety of drugs and medical devices.

5) Natural population cohort database: the (to be) established natural population cohort and special disease cohort database.

6) Omics-related databases: databases that collect information on the physiology, biology, health, behavior, and possible environmental interactions of patients, such as pharmacogenomics, metabolomics, and proteomics.

7) Death registration database: a database formed by death registries jointly confirmed by hospitals, centers for disease control and prevention (CDC), and department of household registration.

8) Mobile devices: mobile devices such as wearable devices that measure relevant data.

9) Other special data sources: databases created for special purposes, such as national immunization program databases.

1. Data Quality Evaluation

The quality of real-world data is mainly assessed by its relevance and reliability.

1) Relevance: Important relevant factors to assess the suitability of real-world data for regulatory use include, but are not limited to:

① the inclusion of important variables and information related to clinical outcomes, such as drug use, patient demographic and clinical characteristics, covariates, outcome variables, follow-up duration, sample size, etc.;

②whether the definition of clinical outcome is accurate and the corresponding clinical significance is meaningful;

③Accurate and representative definition of target population;

④The study hypothesis can be evaluated through the study protocol and statistical analysis plan.

2) Reliability: The reliability of real-world data is mainly evaluated by data integrity, accuracy, quality assurance, and quality control.

①Integrity: missing data problems are inevitable in the real-world setting, but the amount of missing should have a certain limit. For different studies, the degree of missing data may vary. When the proportion of missing data within a specific study exceeds a certain limit, there is a great deal of uncertainty about its impact on the study conclusion. At this time, it will be necessary to carefully assess whether the data can be used as real-world data that produce real-world evidence.

②Accuracy: the accuracy of the data is critically important and needs to be identified and verified against authoritative sources of reference. For example, the measurement of blood pressure requires the use of a calibrated sphygmomanometer, for which and the measurement process is subject to the operating specifications; whether the endpoint event is determined by an independent endpoint event committee, etc.

③ Quality Assurance: quality assurance refers to the prevention, identification, and correction of data errors that occur during the course of the research. Quality assurance is closely related to regulatory compliance and should run through every aspect of data management that needs to have a corresponding Standard Operating Procedures (SOPs).

④Quality Control: data collection, modification, transmission, storage, and archiving, as well as data processing, analysis, and submission, are all subject to quality control to ensure that the real-world data are accurate and reliable. It is necessary to develop a complete, normative and reliable data management process or protocol.

1. Data criteria

Data standards, in the form that information technology systems or scientific tools can use, help ensure that the submitted data are predictable and consistent. In order to manage real-world data from multiple sources, it is necessary to convert the data into a common format with a generic formulation (e.g., terminology, vocabulary, coding scheme, etc.).

In addition, whether the quality of real-world data can support drug development depend on key factors including (but not limited to): whether there is a clear process and qualified personnel for data collection; whether a common defining framework, i.e., the data dictionary, is used; whether the common time frame for key data points collection is followed; whether a study plan, protocol and/or analysis plan related to the collection of real-world data have been established; whether the technical approach used for data element capture, including integration of data from various sources, data records of drug use, links to claims data etc., is adequate; whether patient recruitment minimizes the bias and reflects the true target population; whether data entry and transfer are useable and timely; and whether adequate and necessary patient protection measures such as patient privacy protection and regulatory compliance with informed consent are in place.

1. Real-World Evidence

Real-world evidence is clinical evidence about the use and potential benefits or risks of medical products, obtained through the analysis of real-world data. This definition is not limited in concept to obtaining evidence through retrospective observational studies, but also allows prospective access to a wider range of data to form evidence, through particular study designs including pragmatic clinical trials (PCTs).

1. **Scenarios where real-world evidence supports drug development and regulatory decisions**

Real world evidence may support drug development through a variety of ways, covering pre-marketing clinical development and post-marketing evaluation. Any use of real-world evidence for the purpose of product registration will require adequate communication in advance with regulatory authorities to ensure alignment on the study objectives and methodology.

1. Treatment for rare diseases

In addition to the challenges in subject recruitment, clinical trials for rare disease also face difficulties in the choice of control arm, given the few or lack of treatment options. Therefore, external controls established based on real world data in natural disease cohorts can be considered.

External controls are primarily used for non-randomized single-arm trials, as a historical or in-parallel control. Historical external controls are based on real-world data obtained earlier; parallel external controls are based on data from disease registries constructed simultaneously with the single-arm trial. The use of external controls should take into account the impact of the heterogeneity and comparability of the target population on the corresponding real-world evidence.

1. Revision of indications or drug combination labeling

For drugs that are already marketed, long-term clinical practice may find it necessary to expand the indication, and RCTs are often utilized to support the indication expansion. When an RCT is not feasible or when evidence it generates is not optimal, a PCT could be a reasonable choice. For example, clinical practice may find that a new drug for diabetes can potentially benefit patients with cardiovascular diseases (such as heart failure). In that case the subject recruitment into an RCT will be difficult with potential ethical issues and therefore the use of a PCT design may be more feasible.

In terms of pediatrics medication, there are often cases of off-label usage in clinical practice. For that reason, the use of RWE in supporting the expansion of targeted population is also a viable strategy in drug development.

A typical use of real-world evidence to support the development of Bevacizumab, a humanized monoclonal antibody of the vascular endothelial growth factor (VEGF). In 2015, Bevacizumab was approved in China in combination with chemotherapy (carboplatin and paclitaxel) for the first-line treatment of late stage unresectable advanced, metastatic or recurrent squamous non-small cell lung cancer. However, the real-world use of chemotherapy with Bevacizumab also includes Pemetrexed in combination with platinum, Gemcitabine and Cisplatin. In October 2018, Bevacizumab was approved to expand the treatment regimen with a combination of platinum-based chemotherapy, based on the strong supporting evidence from three real-world studies. These studies retrospectively analyzed patient data from three hospitals and showed that the combination of Bevacizumab with platinum-based chemotherapy significantly prolonged PFS and OS compared with chemotherapy alone, and no new safety issues were identified. This finding was consistent with global population data. In addition, relevant real-world studies have also provided data in different patient subgroups such as those with EGFR mutations or brain metastases, confirming the efficacy and safety of Bevacizumab combination therapy from multiple perspectives.

1. Post-marketing evaluation

Due to factors such as limited sample size, short study duration, strict enrollment criteria, and standardization of intervention, drugs approved based on RCTs usually have limited safety information, lack of generalization of efficacy conclusions, less optimal drug regimen, and insufficient health economic benefits. As a result, there is a need to use real-world data for more comprehensive assessment of these aspects of the approved drugs, and to refine the decision making based on the real-world evidence from natural populations on a continuous basis.

For example, a drug for cardiovascular diseases has been approved in more than 50 countries/regions worldwide. In the multi-regional clinical trials that supported it approval, small number of Chinese subjects resulted in limited number of cardiovascular events and short drug exposure in the Chinese subgroup. This has led to greater variability in the efficacy results in the Chinese population. As an overseas marketed drug with clinically urgent needs in China, to further evaluate the efficacy of this compound in Chinese patients, the applicant plans to conduct a prospective, observational, post-marketing real-world study to evaluate the combination of the compound with standard treatment versus standard treatment alone, in the prevention of major adverse cardiovascular events (MACE) in Chinese patients with cardiovascular disease.

1. Clinical development of traditional Chinese medicine hospital preparations

Traditional Chinese medicine prepared and used in hospitals have been widely used clinically for a long time without being approved for marketing. This is a unique phenomenon in China. For the clinical research and development of such drugs, if real-world research and randomized controlled clinical trials can be combined, scientific and feasible clinical R&D and regulatory decision-making pathways can be further explored.

For the development of traditional Chinese medicine hospital preparation, there exist multiple R&D strategies that utilize real-world evidence. Figures 2 and 3 outline two potentially possible pathways. The pathway that combines observational studies and RCTs is illustrated in Figure 2. Specifically, stage 1 starts with retrospective observational studies. At this stage effort should be made to collect as much as possible existing real-world data related to the use of the product including all possible covariates, develop data cleaning rules, identify possible controls, assess data quality, and conduct comprehensive and detailed analyses using appropriate statistical methods. If the retrospective observational studies show that the drug has potential benefits for patients in clinical use, it may proceed to the next stage of the development, otherwise the process should be terminated. In stage 2, prospective observational studies can be conducted. Based on the stage 1 research, this second stage can be more carefully designed in terms of several aspects, including data acquisition and its system, data quality control, data cleaning rules, and clearer definition of controls. Once this stage 2 prospective observational research has progressed to certain phase, and if the data are consistent with the results of stage 1 retrospective observational studies by continuing to show clinically meaningful benefits, a third stage of RCT can be conducted in parallel. If needed, a pilot RCT may be conducted first to acquire sufficient information to support the design of the primary RCT. However, if existing evidence from previous observational studies is deemed sufficient, a confirmatory RCT may be designed and conducted directly. In terms of timing, the duration of the RCT may be covered by the stage 2 prospective observational studies, which can be completed at the same time as the RCT or extended for some time after the end of the RCT, depending on the maturity of the real-world evidence.



Figure 2 Potential development pathway for traditional Chinese medicine hospital preparations

Another potentially possible pathway, which combines observational studies with PCTs, is outlined in Figure 3. In the first stage, retrospective observational studies are conducted first. If it is concluded that the drug has potential benefits in clinical practice, it may proceed to the second stage, otherwise the process should be terminated. The second offstage consists of a PCT research, which provides evidence that can be used to support the evaluation of the drug’s clinical efficacy and safety.



Figure 3 Potential development pathway for traditional Chinese medicine hospital preparations

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7. Guiding clinical trial design

Compared with other potential applications, using real-world evidence to guide clinical trial design has more practical utilization. For example, the two potential pathways for the development of hospital-prepared traditional Chinese medicines described in the previous section have used the real-world evidence generated by retrospective observational studies, including for example the disease natural history, the disease prevalence in the target population, the effectiveness of standardized treatments, and the distribution and variation of key related covariates, to provide a basis for the next stage study design. More generally, real-world evidence can provide valid reference for inclusion and exclusion criteria, parameters for sample size estimation, and determination of non-inferiority margins, etc.

1. Identify the target population

Precision medicine aims to better predict the therapeutic benefits and risks of drugs to specific populations (subgroups), and real-world evidence based on real-world data provides the possibility for the development of precision medicine. For example, due to the limited sample size, regular clinical trials often ignore or have limited power to consider subgroup effects in the research plan. This prevents important information on potential treatment responders or high-risk populations with serious side effects from being fully recognized. Through a thorough analysis of real-world data, the treatment benefits and risks in different subgroups can be more adequately assessed, and hence real-world evidence can be obtained to support more precise identification of the target population.

The identification of biomarker is critical for preclinical and early clinical studies of targeted therapies. Using real-world information such as omics data, public gene bank information, and related clinical data in population cohorts, real-world evidence can be generated through various contemporary data mining techniques such as machine learning, which can in consequence support the precise identification of population for targeted therapies.

1. **The Basics of Real-World Research Design**
2. Pragmatic clinical trials

Pragmatic Clinical Trials (PCT), also known as practical clinical trials, refer to clinical trials that are designed and conducted in an environment close to the real-world clinical practice. They represent a type of study between RCTs and observational studies. Unlike RCTs, PCT interventions can be either standardized or non-standardized; subjects in the PCTs can be randomized or allocated per pre-defined criteria; the inclusion criteria for the subjects are often less restrict and considered more representative of the target population, and the evaluation of intervention outcomes may not be limited to clinical efficacy and safety. On the other hand, unlike observational studies, PCTs are intervention studies, although the interventions are often designed with additional flexibility.

Since a PCT needs to consider the impact of all potential factors, including especially various biases and confounding factors, its study design and statistical analysis are usually complicated, and the required sample size can be much larger than a regular RCT design. PCTs, when randomization is utilized, will reduce the impact and biases of the confounders and thus provide a generally speaking robust causal inference. In addition, PCTs do not adopt blinding in most cases, therefore sufficient attention should be paid in estimating and adjusting the resulting detection bias. Since PCTs are conducted in a setting close to real clinical practice, the evidence obtained by PCTs is considered as the most reasonable and practice real-world evidence compared to other research types.

1. Single-arm trial using real world data as control

The use of external controls has limitations, mainly including different medical environments, changes in medical technology over time, different diagnostic criteria, different outcome measures, different baseline condition of patients, diverse interventions, data quality, etc. These limitations result in additional challenges in the comparability of research subjects, the accuracy of research results, the reliability and extrapolation of research conclusions.

To address these limitations, it is first necessary to ensure that the collected data meet the relevant quality requirements of real-world data. Secondly, in terms of design, the use of parallel external controls is generally superior to historical controls. Prospective parallel external controls can use disease registration models to ensure that data records are as complete and accurate as possible. Third, appropriate methods shall be adopted for statistical analysis, such as the Propensity Scores (PS) method and Virtual Matched Control method.

1. Observational studies

The data collected from observational studies are undoubtedly the closest to the real world, but their most notable limitations are the existence of various biases, data quality is difficult to guarantee, and observational and unobserved confounding factors are difficult to identify. These challenges leave the study conclusion with large uncertainty.

Whether the data collected from observational studies are appropriate to generate real-world evidence to support regulatory decisions depend on a few areas of focus: ①What are the data characteristics? (e.g., collection of relevant endpoints, consistency of records, description of missing data, etc.) ②What are the characteristics of the research design and analysis? (e.g., is there an appropriate positive control? Is the non-inferiority design applicable considering potential untested confounders as well as potential measurement variability?) ③What sensitivity analyses and statistical diagnostic methods are pre-determined to analyze real-world data?

The key technique for analyzing real-world data from observational studies is causal inference. The statistical analysis methods commonly used in real-world studies are summarized in Appendix 2.

1. **Evaluation of Real-World Evidence**

The evaluation of real-world evidence should follow two main principles: whether the real-world evidence can support the scientific questions that need to be answered; and whether the existing real-world data can be scientifically analyzed to obtain the required real-world evidence.

1. Real world evidence and the scientific questions it supports

Prior to the decision to use any evidence including real world evidence, the scientific questions under evaluation should first be clearly defined. For example, the safety considerations for the use of drugs in combination with other drugs after marketing; the expanded indications for approved products; and the establishment of robust and reliable historical controls for a single arm clinical trial. The original intention of using real-world evidence should be considered: is it because the corresponding scientific question is facing real world, or it is because traditional clinical trials cannot be effectively implemented. If the latter, whether or not the real-world evidence can replace traditional clinical trials, answer the same questions and arrive at robust conclusions, should be used as important guidelines for measuring real-world evidence applications.

1. How to transform real-world data to real-world evidence

To answer this question, a few key factors need to be considered:①The research environment and data acquisition need to be close to the real world, such as a more representative target population, diversity of interventions compatible with clinical practice, or natural selection of interventions; ②Use of appropriate controls; ③More comprehensive evaluation of drug effectiveness; ④Effective bias control, such as the use of randomization, harmonization of measurement and evaluation methods, etc.; ⑤Appropriate statistical analyses, such as the correct use of causal inference methods, reasonable handling of missing data, adequate and sufficient sensitivity analyses, etc.; ⑥Reasonable interpretation of results; ⑦Consensus among the key stakeholders.

Finally, it should be emphasized again that all study designs, assumptions, and specific definitions and methodologies relevant to the generation of real-world evidence should be clearly defined in advance in the study protocol. In the meanwhile, any use of real-world data and evidence with the ultimate expectation of drug registration would require sufficient communication with regulatory authorities in advance, in order to ensure mutual agreement on study objectives and methods. Post-hoc remedial data citation, definition, analysis, and interpretation are generally not acceptable for regulatory decisions.

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**Appendix 1: Glossary**

**Patient Registry**: A system of collecting standard clinical and other data, using an observational research approach, to evaluate specific disease, condition, or specific outcome in the exposed population, for one or more predefined scientific, clinical, or policy objectives.

**Single-arm (One-arm) Clinical Trial**: A non-randomized clinical trial where only the experimental group is set up. A single-arm trial, usually uses external controls based on historical data or in a parallel manner.

**Observational Study:** A study that explores the outcomes in natural or clinical populations without active intervention, based on specific research objectives.

**Clinical Trial:** An interventional clinical research in which one or more interventions, possibly including placebo or other controls, are prospectively assigned to human subjects to assess the impact of these interventions on health-related biomedical or behavioral outcomes.

**Retrospective Observational Study:** An observational study based on historical data (generated before the start of the study).

**Prospective Observational Study:**  An observational study based on data to be collected prospectively based on a preset research plan.

**Comparative Effectiveness Research:** A research method, by considering both individuals and the population in an environment as close as possible to the real world, that evaluates the clinical effectiveness and safety, social effects, and economic benefits of a particular intervention. Such evaluation helps key stakeholders such as patients, doctors, policy makers, and service consumers to improve healthcare services so that the most appropriate interventions or strategies can achieve the optimal outcomes in the most appropriate target population and timing.

The comparative effectiveness research is based on the real world, with a wide range of applications focusing on the decision-making for the natural population. Therefore, it is necessary to consider the impact of many factors on the outcome as comprehensively as possible. The designs are often more complex with usually a large sample size. In the meanwhile, there are clear requirements for valid statistical analysis in terms of causal inference.

**Pragmatic Clinical Trial (PCT, a.k.a. Practical Clinical Trial)**: A clinical trial that is designed and conducted in an environment as close as possible to the clinical real world. It is a type of research between RCTs and observational studies. Unlike RCTs, PCT interventions can be either standardized or non-standardized; subjects in the PCTs can be randomized or allocated per pre-defined criteria; the inclusion criteria for the subjects are often less restrict and considered more representative of the target population, and the evaluation of intervention outcomes may not be limited to clinical efficacy and safety. On the other hand, unlike observational studies, PCTs are intervention studies, although the interventions are often designed with additional flexibility

**Data Standard：**A set of rules on how to construct, define, format, or exchange specific types of data between computer systems. Data standards allow the submission of information to be predictable and consistent, and in forms that information technology systems or scientific tools can use.

**Randomized Controlled Trial (RCT):** A clinical trial that utilizes a randomization method in subject assignment to experimental and appropriate control groups.

**External Control**: The control in clinical trials established based on data outside the scope of the study, such as real-world data, to evaluate the effects of the interventions under investigation. External controls can be historical data or data obtained during the same period of time in a parallel manner.

**Medical Claims Data:** A compilation of information on medical claims submitted to insurance companies for access to claims for treatments and other interventions.

**Causal Inference:** An inferential action,often based on real-world data, that characterizes the causal relationship between interventions or exposures to clinical or health outcomes, taking into account the effects of various covariates and measured or unmeasured confounders and controlling possible biases. Appropriate statistical models and analytical methods should be used to establish the conclusions and causal relationship.

**Real World Data (RWD)**: Data collected for a patient’s health status and/or derived from various routine medical processes that can be analyzed to potentially form real-world evidence.

**Real World Research/Study (RWR/RWS)**: As part of the CER, an RWR/RWS refers to the collection of patient-related data in a real-world environment to, through analysis, acquire clinical evidence (real-world evidence) of the value and potential benefits or risks of medical products. The main research type is observational, but it can also be pragmatic clinical trials.

**Real-World Evidence (RWE)**: Clinical evidence on the use and potential benefits or risks of medical products obtained through the analysis of real-world data.

**Appendix 2: Common Statistical Methods for Real-World Research**

As compared with RCTs, causal inference in real-world studies requires special attention to adjustment for confounding effects. Therefore, there is often a need for relatively complex statistical models and analytical methods. These methods include both classical statistical methods, such as conventional multivariate regression, and also some relatively more cutting-edge and sophisticated ones, such as propensity score matching and instrumental variables. This guidance only provides a general description of these statistical methods. More specific methods and application details can be found in the references provided and do not preclude the appropriate use of methods that are not described here.

1. Descriptive and Unadjusted Analyses

For descriptive analysis, appropriate descriptive statistics and statistical plots can be selected according to different data types, including: the range for continuous/numerical variables, dispersion and central tendency, counts and percentages for categorical variables, and graphs that describe the distribution of data. For real-world research, correct and effective descriptive statistical analyses can play an important role. For example, in disease registry cohort studies, stratified descriptive statistics of relevant covariates by levels of exposure factors can help to examine their distribution balance; in propensity score matched datasets, summary statistics by group of relevant covariates by exposure factors can help to identify imbalances in residuals after the matching, etc.

Univariate or unadjusted hypothesis testing, such as two-sample *t* test, can be used to assist in the identification of covariates related to exposure factors and/or study outcomes. For real-world studies, where possible confounding effects often need to be identified and considered from within a large number of covariates, extensive and comprehensive exploratory analyses of relevant subject characteristics using descriptive statistics are generally necessary.

1. Adjusted Analyses
2. Selection of Covariates
* When using causal inference methods that adjust for covariates, the selection of covariates selection is often a frontend question. Generally, methods for covariate selection belong to one of the two categories. One is, based on a causal network based on the exposure-to-outcome relationship, to identify risk factors, confounders, intermediate variables, time-varying confounders, collider variables, and instrumental variables. Risk factors and confounders should be included as covariates in the model, while the inclusion of intermediate variables, collider variables, and instrumental variables should be avoided:
* **Risk Factor:** Baseline covariates that are predictive of the outcome variable but have no effect on the level of the treatment/exposure factor. In the causal relationship as shown in Figure 1, wheredenotes the risk factor, indicates treatment or exposure factors,  denotes the outcome variable. Any adjustment to does not affect the estimation of the effect from, i.e., such adjustment does not introduce or reduce bias, but instead can improve the estimation precision and model efficiency.

*R*

*A*

*Y*

Figure 1. Causal relationship between risk factors () and outcome variables ()

* **Confounder**: Factors that affect both the level of treatment/exposure factors and are predictive for outcome variables. Certain confounders are measured, but there are also those that have not been measured. In the causal relationship as shown in Figure 2, whereindicates treatment or exposure factors,denotes the outcome variable,and are two unmeasured confounders, represents a measured confounder. In such case, (can be a proxy variable for  such that an adjustment on can eliminate the confounding impact of on the outcome .

*A*

*U*2

*Y*

*U*1

*C*

Figure 2. Causal relationship between measured confounding variables (), and unmeasured confounding variables (,)

**- Intermediate Variable:** Variables that may or may not be on the treatment-outcome causal pathway after treatment or exposure. As shown in Figures 3a and 3b, respectively, whereindicates treatment or exposure factors, represents the outcome variable at the moment of measurement,denotes the intermediate variable, indicates an unmeasured confounder between and . To estimate the total effect of, in case of Figure 3a, Fig.The total effects are divided into direct effects and indirect effects. an adjustment on  may eliminate the indirect effect, resulting in a biased estimation of the total effect; and in case of Figure 3b, an adjustment on A will introduce correlation between  and , which are originally independent, and consequently  into a confounding factor in the causal relationship from, and result in a biased estimation of the total effect if no appropriate adjustment to  is made. Also, especially in real-world studies, bias can be introduced due to over-adjustment if the covariates being adjusted for are not those measured at baseline.

*M*

*Y*

*A*

Figure 3a. Causal relationship between treatment () and outcomes (), with an intermediate variable ()

*M*

*Y*

*A*

*U*

Figure 3b. Causal relationship between treatment () and outcomes (), with an intermediate variable () and an unmeasured confounder ()

**- Collider Variable**: In a causal relationship, if a variable has two independent parental nodes, then such variable is considered a collider. An adjustment to the collider may introduce correlation between the parental nodes, which are originally independent, and may bring additional confounding effect between the exposure and outcome, leading to a biased estimation of causal relationship. In a causal relationship as shown in Figure 4, wheredenotes an unmeasured confounder between variable *L* and outcome *Y*, denotes an unmeasured confounder between variable *L* and exposure factor *A.* In such case the variable *L* becomes a collider, with and being two independent parental nodes.An adjustment to L will introduce correlation between and, which are originally independent, and may bring additional confounding effect between the exposure and outcome, leading to a biased estimation of the causal relationship between . It might be noted that the intermediate variable *M* in Figure 3bis also a collider variable.

*U2*

*A*

*Y*

*L*

*U1*

Figure 4.Causal relationship between treatment () and outcomes (), with a collider variable ()

**- Instrumental Variable:** A pre-treatment variable that has a causal effect on the level of a treatment or exposure factor, but has no causal association with the outcome variable other than indirectly affecting the outcome variable through the effect of the exposure factor. The instrumental variable is independent of confounders of exposure and outcome. In a causal relationship as shown in Figure 5, where  indicates the confounding factors between exposure factors,  and outcome . In this case,is an instrumental variable. If the instrumental variables are adjusted in a statistical analysis by being directly incorporated into the model, the confounding impact of might be enlarged. On the other hand, certain analysis methods for instrumental variables may be used to eliminate confounding effects (see Estimation of instrumental variables).

*Z*

*A*

*Y*

*U*

Figure 5.Causal relationship between treatment () and outcomes (), with an instrumental variable ()

In reality, the true complete network structure is unknown. During practical applications, when part of the causal structure is known, existing covariate selection methods can be used, based on relevant professional background knowledge, to adjust all observed baseline variables that may be associated with the outcome, known outcome-related risk factors, and all direct dependent variables for treatment or outcome. Another type of covariate selection method is based on high-dimensional variable selection. The principle is to use the degree of association between response variables to empirically learn the correlation between variables from the data, and select the variables related to the treatment factors and/or outcome variables. Typical methods include forward selection, backward selection, machine learning (such as Boosting, random forest, LASSO method, etc.) and methods for automatic high-dimensional proxy adjustment. These two types of methods can also be used in combination, i.e., first use professional experience to identify a set of variables, and then use appropriate empirical learning methods to further select the covariates to be included in the final analysis model. This has the advantage of limiting reliance on empirical learning, reducing the risk of over-adjustment while also reducing confounding effect.

1. Conventional Multivariate Regression

Regression analysis is a common strategy for adjusting the influence of potential confounding variables and estimating treatment effects. Generally, the variables to be adjusted are variables that are simultaneously related to the study's treatment factors and outcome measures, and are located before the treatment factors on the causal pathway. If an intermediate variable is located on the treatment-to-outcome pathway, an adjustment to it may eliminate some of the treatment effects, resulting in a bias due to over-adjustment. There are extensive applications in observational studies where traditional multivariate regression methods are used to directly adjust for potential confounding and effect modifying factors. These methods are also applicable in real-world studies. The use of regression analysis methods requires attention to whether the corresponding model assumptions are valid. For example, the linear regression model assumes that the mean of the outcome variable is a linear function with respect to the covariates. Therefore, this assumption needs to be verified before choosing a linear regression approach. In addition, whether to choose a regression model or other methods also depends on the characteristics of the data. For example, if the number of events in a study is sufficiently large (e.g., 8-fold or more than 10-fold the number of covariates) relative to the number of covariates included in the model and the treatment factor is not uncommon, the traditional logistic regression approach is a reasonable option and may be considered as the primary analysis method. Otherwise, alternative methods that are more appropriate should be considered. In addition, all regression analysis methods have potentially the risk in extrapolation, that is, the support of the fitted model is actually outside the range of the sample data. To assess the risk of extrapolation, statistical methods such as propensity scores can be used.

In the situation where the number of covariates is large, methods like the stepwise approach may help in establishing a more efficient model. However, it should always be noted that there may be certain level of subjectivity, depending on the actual variable selection method and criteria (e.g., p-value ≤ 0.1 for the corresponding parameter of interest). Also, for covariates with a meaningful but relatively modest effect on disease risk, the final model identified using independent variable selection methods may miss these important covariates. Furthermore, the use of a stepwise regression approach may lead to an underestimation of the standard error in the estimation of the model parameters. Another strategy is to use composite covariates such as Propensity Score (PS) or Disease Risk Score (DRS) in the regression. In cases where the outcome event is relatively rare (eg, less than 8-fold of the number of covariates), the propensity score method is often superior to the traditional logistic regression method; however, in cases of rare treatment/exposure (ie, only a small number of subjects in a particular treatment group) but the number of outcome events is large, the traditional logistic regression method is generally superior to the PS method.

1. Propensity Score

The propensity score method, proposed by Rosenbaum and Rubin, is a method that adjusts the effect of confounders in the situation where a large number of covariates exist. Let  denote all observed covariates, indicates the treatment or exposure factors of interest (indicates exposure), then the propensity score is defined as the probability that an observed subject receives a certain treatment (or exposure) under the observed covariate condition. The propensity score provides a composite summary of the effects of characteristic variables and reflects the level of balance of all observed covariates between the two groups. Rosenbaum and Rubin have demonstrated that, if the adjustment for raw covariates effectively controls the confounding effects, adjusting only the propensity scores based on these covariates is also sufficient to control for confounding effects. Propensity scores can often be estimated by regression models, such as commonly used logistic regression models with observed covariates as independent variables and treatment as dependent variables:



Propensity score methods are particularly appropriate in cases where treatment (or exposure) factors are common but outcome events are rare, or where multiple outcomes may exist. Propensity-Score Matching, Stratification/Subclassification, Inverse Probability of Treatment Weighting (IPTW), and the method of including Propensity Score as the sole covariate in the statistical model for adjustment analysis are all commonly used.

When utilizing the propensity score for causal estimation, it is important to first judge whether the covariate distribution is balanced between treatment groups for patients with a propensity score close to each other. The methods of judgment include, but are not limited to, visual inspection of the distribution of propensity scores across treatment groups after PS adjustment, or a statistical test of subject covariates across treatment groups. If the coincidence of the propensity score distribution between different groups is not high, the effect estimate obtained from the adjusted analysis using the propensity score remains at the risk of bias. Remediation schemes such as restricting the range of study subjects to overlapping regions of the distribution of propensity scores across groups may be considered in case of poor coincidence.

When possible, matching is a good application method for propensity scores. If it can be coupled with the previously mentioned methods that limit the range of the study subject, the overlap of propensity score distributions among groups may be further improved. In addition, if the summary results of the between-group equalization of all study covariates after matching are provided, such as plotting the statistics or calculating the standardized differences for each covariate before and after adjustment (after-adjustment standardized difference is usually expected to be lower than 20%), and comparing them with the results of the covariate balance of randomized clinical trials, it will be helpful to evaluate the matched effect. However, propensity score matching methods can only control the known and observed covariates. Their impact on unknown or unobserved confounders, the effect of the balancing, and the robustness of the analysis results will need to be evaluated using other approaches. Note that the standard error of the causal effect estimate based on the matched design will be different from the unmatched case.

Covariates included in the propensity score model should be the confounding variables or those associated with the outcome variables. Otherwise, the variance of the estimator will increase if only the variables that are related to the exposure factor are included. Traditional regression adjustment method and propensity score matching method each has advantages and disadvantages. The former does not guarantee that the study covariates are balanced, and the latter may lead to a decrease in sample size. Therefore, further sensitivity analysis is very necessary.

1. Disease Risk Score

Disease risk scores are similar to propensity scores and are a composite measure based on all covariates. Let denote all observed covariates,  denote the treatment or exposure factors of interest (denote exposure), then the disease risk score is defined as the probability of an outcome event under the assumption of no treatment/exposure or specific covariate conditions.

Generally speaking, the methods for estimating DRS can also fall into one of the two categories. The first type of method uses all observations of the study sample in fitting a regression model, taking treatment and covariates as independent variables, study outcomes as the dependent variable. For example, for a logistic regression model

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Once fitted, the DRS values for each study subject can be calculated by substituting the covariate values into the model and setting the treatment to be the control group. With that, the treatment-to-outcome causal effect can be estimated by analyzing the data stratification by DRS. The second type of method uses only the study data of the control (non-exposed) group, historical data before the treatment factor occurs, or sample data without (or low incidence of) treatment factor to fit the DRS model. For example, for a logistic regression model as follows



Once fitted by using only the control group data, the DRS values for each study subject can be calculated by substituting the covariate values into the model.

Different from the PS method, for studies where outcome events are common but treatment (exposure) factors are rare or there may be multiple levels of treatment, the DRS approach is a good option to balance baseline disease risk across groups. In particular, in case of multiple levels of treatment (exposure) factors, where some of them are sparse, it is often recommended that the DRS method be selected instead of the PS method.

1. Instrumental Variables

One common limitation of the previously mentioned methods (conventional regression, PS, DRS) is that only measured confounding factors can potentially be controlled. On the other hand, the causal inference based on instrumental variables does not require the specification of what confounders/covariates to be adjusted, and so the impact of unmeasured confounders can also be potentially controlled during the analysis. A variable is considered an instrumental variable if it is related to the treatment factor, and the effect on the outcome variable can only be achieved by influencing the treatment factor without being correlated with the potential confounders. After the instrumental variables are identified, even with the existence of unmeasured confounders, the treatment-to-outcome causal effect can be estimated by separately estimating the effect of instrumental variables on the treatment and that on the outcome, and then contrasting the two estimated effects.

The biggest challenge in using instrumental variables to estimate causal effects lies in the identification of suitable instrumental variables.

First, instrumental variables cannot be associated with any observed or unobserved confounders of treatment and outcome, otherwise . Second, instrumental variables cannot have a direct effect on the outcome but only an indirect impact through the treatment-to-outcome pathway, otherwise the estimated causal effect may again be biased. Finally, instrumental variables need to be highly correlated with the treatment factor. If the correlation is too weak, in which case the variable is referred to as a weak instrumental variable, the corresponding estimator of the causal effect may perform poorly especially with small sample size, with large estimation variation and potentially enlarged bias. Variables that satisfy the above three conditions can be used as instrumental variables to estimate the treatment-to-outcome causal effects. In practice, however, it might be difficult to find variables that meet the above conditions, and there is no particularly appropriate statistical method to evaluate whether these conditions are completely satisfied.

Once instrumental variables are identified, the estimation of causal effects usually utilizes a two-stage least-squares approach:

Stage 1: Fit a regression that links the treatment factors () and instrumental variables () and obtains the predicted value of the treatment factor;

Stage 2: Build a regression that links the outcome variables *Y* with the predicted value of treatment factors based on the instrumental variable, i.e.,. Wit that, the regression coefficient is an unbiased estimate of the treatment-to-outcome causal effect.

The selection of instrumental variables is particularly important to the estimation of causal effects. The impact of instrumental variables to the treatment factors is expected to be homogeneous and consistent across the entire study population. Otherwise, the estimated causal effect may not represent the average causal effect in the overall population, but only the effect within a certain subpopulation in which the impact of instrumental variables is meaningful, i.e., the Local Average Treatment Effect (LATE). It should also be noted that when the treatment factor is a non-continuous variable, the estimated causal effect and the estimated error obtained by the two-stage least squares method may have potential statistical bias.

1. Missing data consideration

The missing data problem is often inevitable in real-world studies. Not only the outcome variables, but covariates may also be missing. This makes it difficult to assess the comparability of treatment groups, which in turn may lead to biased estimation of treatment effect. Investigators and the Sponsor should optimize the trial design to minimize the missingness rate.

Before conducting the primary analysis, an attempt should be made to determine whether the data are truly missing and, if yes, the reason for the missing. First of all, no data does not mean that the data are missing. For example, a patient did not have a certain examination, or a doctor did not perform certain examination at all. These data should not exist, nor should they be considered as missing data. This is common in real-world data. If there indeed exist missing data, an analysis of the missingness mechanism should be performed. Generally, there are three types of missing mechanism: Missing Completely At Random (MCAR), Missing At Random (MAR) and Missing Not At Random (MNAR). Missing completely at random means that the missing data are independent of the measured or unmeasured covariates and outcome variables. Let $Y$ denote the outcome variable ($Y\_{mis}$ for missing data and $Y\_{obs}$ for the observed data) and $X$ the treatment and associated baseline covariates. Let R be an indicator for missingness ($R=0 $for missing and $R=1$ for non-missing), then the missing completely at random can be expressed as:. Missing at random refers to the case that the missing data are independent of the potential outcome conditional on the measured covariates and outcome variable, i.e.. Finally, if the data are missing not at random, the missing data may depend on the value of the missing data themselves, and may also be related to the measured covariates and outcome data.

For missing data problems, selecting the appropriate methods for imputation and analysis is an effective way to avoid bias and information loss. If no imputation is performed and only observations with no missing data are analyzed, then regardless of the missing mechanism, the study efficiency will be reduced due to reduced sample size. When the characteristics of subjects with missing data differ from those with complete data, excluding missing data also results in biased treatment effect estimates. Imputation methods should be established based on appropriate assumptions on missing mechanisms and clinical problems. In general, for missing completely at random cases, imputation with sample means or predicted values of generalized estimating equations will suffice. Or, the analysis can be based on the complete data only. For missing at random cases, a statistical model can be constructed to predict the value of  with covariates. Multiple Imputation (MI) methods are generally recommended, such as traditional regression model methods, Markov Chain Monte Carlo (MCMC) methods, and Fully Conditional Specifications (FCS). In addition, for the missing at random case in a longitudinal study, the Mixed Model for Repeated Measures (MMRM) can be used. It should be noted that although the MMRM method is recommended for handling missing data, it does not impute the missing data. For the case of missing not at random, the Pattern Mixture Models (PMM) method can be applied to construct different statistical models for missing and non-missing data.

In addition, there is a single value imputation method, which utilizes simple principles and is easy to implement. However, even under the assumption of missing at random, the single value imputation cannot guarantee a valid result, and the variability of missing data is not considered, either. Therefore, it is generally not recommended for the primary analysis.

In observational studies with missing covariates, according to the specific pattern of missingness, a number of existing statistical methods may be considered, including complete data analysis, multiple imputation (MI) and propensity score (PS).

The complete data analysis method performs statistical analysis by excluding patients with missing covariates (or patients with missing follow-up in cohort studies). This will reduce the power of the statistical test. Note that this method can provide unbiased estimates of treatment effect only when the missing data are not correlated with the study design nor the treatment factors.

Multiple imputation method (MI) takes into account the uncertainty of the missing values and impute the missing data multiple times with possible values. As previously stated, the MI is typically performed under the assumption of missing at random, implying that the missing data may potentially associate with observed covariates but not with unobserved variables. Since MI produces multiple datasets, two methods can be used for estimating propensity scores, i.e., estimating based on each imputed data, or estimating based on all imputed data. Rubin's method may be used to combine multiple treatment effects that simultaneously account for variability within and between imputed data.

It needs to be clarified that the assumption on any of the three types of missing mechanism (MCAR, MAR, and MNAR) are generally not verifiable and can only be justified through a correct description and understanding of the data collection process.

It should be noted that there is no optimal way to deal with missing data, and no method can yield the same robust and unbiased estimates as the one based on the complete data. The best strategy to deal with missing data is not to plan how to analyze the data, but rather to control the chance of missing data by optimizing the study design and implementing it with good practice.

4. Sensitivity Analysis

The various causal inference methods mentioned previously all have their own applicable conditions and model assumptions. For example, the propensity score matching method does not need to satisfy the model assumptions of the instrumental variable method, while the instrumental variable method is able to handle situations where the propensity score method is not applicable (eg, with the existence of unmeasured confounders). Therefore, for the choice of statistical methods for causal inference, sensitivity analyses can be performed to evaluate the robustness of the analysis by using different statistical models, thereby prioritizing statistical models with good robustness. A more comprehensive sensitivity analysis can be found in the Guidelines for the Development of an Observational Effectiveness Comparative Study Plan.

Finally, like other confirmatory studies, the interpretation of analysis results for real-world studies should be as comprehensive, objective, accurate, and adequate as possible, not only emphasize statistical significance (such as P-values and confidence intervals), but also focus on Clinical practical significance; not only depend on the final conclusion, but also on the logic and integrity of the entire evidence chain that supports the conclusion; not only depend on the overall effect, but also on the subgroup effect. In addition, a detailed elaboration on the control and impact of various possible biases and confounding should be provided as well.

**Appendix 3: Chinese-English Vocabulary**

|  |  |
| --- | --- |
| English | 中文 |
| 21st Century Cures Act | 21世纪治愈法案 |
| FDA Adverse Event Reporting System, FAERS | FDA不良事件报告系统 |
| Qualification opinion of a novel data driven model of disease progression and trial evaluation in mild and moderate Alzheimer’s disease | 阿尔茨海默病疾病进展和临床试验评估的数据驱动模型新方法的意见书 |
| Standard Operation Procedure, SOP | 标准操作规程 |
| Standardized Differences | 标准化差 |
| Patient Registry | 病例登记 |
| Single-arm/One-arm Trial | 单臂临床试验 |
| Electronic Medical Record, EMR | 电子病历 |
| Electronic Health Record, EHR | 电子健康档案 |
| Multiple Imputation, MI | 多重填补 |
| Missing Not At Random, MNAR | 非随机缺失 |
| Stratification/Subclassification | 分层法 |
| Risk Factor | 风险因子 |
| Instrumental Variable | 工具变量 |
| Observational Study | 观察性研究 |
| Center for Drug Evaluation, CDE | 国家药监局药品审评中心 |
| CASSA | 国家药品不良反应监测哨点联盟 |
| Patient Reported Outcome, PRO | 患者报告结局 |
| Retrospective Observational Study | 回顾性观察性研究 |
| Confounder | 混杂因素 |
| Baseline Observation Carried Forward, BOCF | 基线观测值结转 |
| Disease Risk Score, DRS | 疾病风险评分 |
| Regulatory Compliance | 监管合规性 |
| Local Average Treatment Effect, LATE | 局部平均处理效应 |
| Clinical Trial | 临床试验 |
| Markov Chain Monte Carlo, MCMC | 马尔科夫链蒙特卡洛模拟 |
| The American Recovery and Reinvestment Act | 美国经济复苏刺激法案 |
| Federal Food, Drug, and Cosmetic Act, FD&C | 美国联邦食品，药品和化妆品法 |
| Food and Drug Administration, FDA | 美国食品药品监督管理局 |
| Pattern Mixture Models, PMM | 模式混合模型 |
| Last Observation Carried Forward, LOCF | 末次观测值结转 |
| Inverse Probability of Treatment Weighting, IPTW | 逆概率加权方法 |
| European Medicines Agency, EMA | 欧盟药物管理局 |
| Collider Variable | 碰撞节点变量 |
| Prospective Observational Study | 前瞻性观察性研究 |
| Propensity Scores, PS | 倾向性评分 |
| Propensity-Score Matching | 倾向性评分匹配法 |
| Hot-Deck Imputation | 热卡填补 |
| International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use, ICH | 人用药品注册技术要求国际协调会 |
| Pharmaceutical and Medical Devices Agency, PMDA | 日本医药品医疗器械综合机构 |
| Time-varying Confounder | 时变型混杂因素 |
| Comparative Effectiveness Research, CER | 实效比较研究 |
| Pragmatic Clinical Trial, PCT | 实用/实操临床试验 |
| Adaptive Licensing Pilot | 适应性许可试点项目 |
| Data Standard | 数据标准 |
| Randomized Controlled Trials, RCT | 随机对照临床试验 |
| Missing At Random, MAR | 随机缺失 |
| Conditional Mean Imputation | 条件均值插补 |
| External Control | 外部对照 |
| Extrapolation | 外推 |
| Missing Completely At Random, MCAR | 完全随机缺失 |
| Completeness | 完整性 |
| Health Information System, HIS | 卫生信息系统 |
| Vascular Endothelial Growth Factor, VEGF | 血管内皮生长因子 |
| Medical Claims Data | 医保数据 |
| Causal Inference | 因果推断 |
| Real World Data, RWD | 真实世界数据 |
| Real World Research/Study, RWR/RWS | 真实世界研究 |
| Real World Evidence, RWE | 真实世界证据 |
| Quality Assurance | 质量保证 |
| Quality Control | 质量控制 |
| Intermediate Variable | 中介变量 |
| Mixed Model for Repeated Measures, MMRM | 重复测量混合效应模型 |
| Accuracy | 准确性 |
| Worst Observation Carried Forward, WOCF | 最差观测值结转 |