IMPROVING ADR REPORTING EFFICIENCY OF ACTIVE AND PASSIVE SURVEILLANCE IN PHARMACOVIGILANCE

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Abstract

Pharmacovigilance is a significant component of providing safety to drugs through monitoring and evaluation of adverse drug reactions (ADRs). Efficient reporting of ADRs is crucial in the identification of potential drug risk factors, the reduction of harm to patients, and the enhancement of therapeutic outcomes. The success of ADR reporting, however, is compromised by underreporting, limited awareness among patients and healthcare workers, and inefficiencies in available surveillance systems. Two of the most prevalent methods used in pharmacovigilance for detection and recording of ADRs are active and passive surveillance. Passive reporting reliant on voluntary reporting is typically derailed by problems of data incompleteness and reporting deficiencies. Active surveillance involving active intervention such as patient follow-up interview, electronic health record use, and targeted monitoring is however costly and difficult to implement on a large scale. These drawbacks hamper timely ADR detection and compromise patient safety. The purpose of this project is to look for ways of maximizing ADR reporting efficiency within the active and passive surveillance systems. Some of the primary approaches include improving training of health care workers and awareness among the population, integrating enhanced digital reporting tools, using artificial intelligence and big data analysis for real-time monitoring, and strengthening regulatory interventions supporting systematic documentation of ADRs. Additionally, collaborations of regulatory agencies, drug companies, and health care agencies can support better data sharing and utilization. Through the elimination of inefficiencies in current ADR reporting systems and the implementation of innovative approaches, pharmacovigilance projects can significantly improve the safety of drugs and deliver better public health outcomes. This project provides an in-depth evaluation of potential remedies to enhance ADR surveillance efficacy and create a robust pharmacovigilance system.

Keywords: Pharmacovigilance, Adverse Drug Reactions, Active Surveillance, Passive Surveillance, Drug Safety, ADR Reporting, Healthcare Monitoring.

1. INTRODUCTION

Pharmacovigilance (PV) is an important branch of the pharmaceutical sciences that deals with the detection, assessment, understanding, and prevention of adverse drug reactions (ADRs) or any other drug-related issue [1]. The World Health Organization has defined ADRs in a standardized manner as noxious and
unintended effects of a medicinal product at usual doses. Drug safety is of utmost concern, as ADRs are a major cause of morbidity, mortality, and economic burden across the globe [2]. With the number of pharmaceuticals reaching the market and the complexity of the therapeutic regimens, permanent monitoring of drug safety is needed. Pharmacovigilance offers a rational process to assess the safety profile of drugs and direct regulatory interventions that safeguard public health [3]. Proper ADR reporting systems are the backbone of the system, facilitating early detection of safety signals and risk reduction interventions. ADR reporting can be divided into active and passive surveillance systems with varying methodologies, strengths, and limitations.

Passive Surveillance: Passive surveillance, or spontaneous reporting, relies on spontaneous reporting of adverse drug reactions (ADRs) by patients, healthcare professionals (HCPs), and pharmaceutical industries. The system is a simple part of pharmacovigilance programs around the globe, with regulatory agencies running databases such as the WHO's VigiBase, the U.S. FDA's MedWatch, and the European Medicines Agency's EudraVigilance [4]. The passive surveillance technique is cheap and allows for wide population coverage. It is nonetheless, plagued by a series of advantages including underreporting possible reporting biases, and delay in detecting safety signals [5].

Active surveillance: entails systematic data collection strategies, including cohort event monitoring, electronic health records (EHRs), and targeted investigations intended for systematic detection of adverse drug reactions (ADRs). This approach improves data integrity, provides comprehensive drug safety assessment, and facilitates early detection of signals [6]. Nevertheless, the use of active surveillance demands high resources, infrastructure, and expertise, which may restrict its

application in low-resource settings [7]. Early and effective reporting of ADRs is vital for public health as it preserves drug safety, minimizes risks, and maximizes therapeutic outcomes. Ineffective reporting of ADRs may result in ongoing use of unsafe drugs, increased hospitalization rates, and increased healthcare expenditure [8]. Drug regulatory agencies rely on sound pharmacovigilance systems to make decisions regarding drug approval, label changes, and withdrawal of unsafe drugs [9]. ADR reporting also plays a significant role in international drug safety by facilitating data exchange and collaborative risk assessment among regulatory agencies, healthcare providers, and drug manufacturers. Improvement of ADR reporting systems strengthens patient safety, builds public confidence in healthcare processes, and promotes a proactive approach to drug monitoring [10].

The aim of this project is to examine the challenges and measures for enhancing ADR reporting efficiency within active and passive surveillance systems. The main aims are:

- Determining the causes of underreporting and inefficiencies in ADR reporting.
- Reviewing current strategies for enhancing ADR reporting.
- Offering technological innovation and policy advice for enhancing pharmacovigilance practices.
- Emphasizing global cooperation and collective action in ADR monitoring.

By taking a systematic review of the literature,this research aims to present valuable knowled ge for enhancing pharmacovigilance systems to promote safer drug practice and better patient outcomes.

2. ADVERSE DRUG REACTION (ADR) SURVEILLANCE IN PHARMACOVIGILANCE

Pharmacovigilance also plays an important role in ensuring drug safety by identifying, evaluating, elucidating, and preventing adverse drug reactions (ADRs). The primary purpose of monitoring ADRs is to reduce risks of drug use and maximize patient safety. Two major methodologies employed for the detection and reporting of ADRs are active and passive surveillance, which possess unique strengths and weaknesses.

Boosting the efficiency of ADR reporting systems is associated with in-depth knowledge about ADR classification along with the establishment of robust surveillance systems to detect and control drug-related risks early [11]. Figure 1 illustrates that continuous surveillance and analysis of adverse drug reactions are responsible for identifying safety concerns, reducing risks, and optimizing the overall safety profile of pharmaceutical drugs.

Figure 1. Importance of Monitoring ADR

2.1 Definition and Types of ADR

Definition of ADR (WHO Perspective)

World Health Organization (WHO) has classified an adverse drug reaction (ADR) as "a response to a medicinal product which is noxious and unintended and which occurs at doses normally used in man for prophylaxis, diagnosis, or treatment of disease, or for modification of physiological function." The above definition points towards the unexpected nature of ADRs, which differentiate them from drug toxicities caused by overdose or dosing mistakes. ADRs have a significant effect on public health, and therefore systematic surveillance with the assistance of pharmacovigilance systems is necessary [12].

Types of ADRs

ADRs are also subclassified into various groups based on their mechanisms, predictability, and severity. The most widely used classification divides ADRs into Type A and Type B reactions with further subclassifications [13].

Type A (Augmented) Reactions: They are dose-proportional, are predictable, and are related to the well-documented pharmacology of a drug. They form the bulk of percent adverse drug reactions (ADRs), around 80%, and examples include common side effects like hypotension induced by antihypertensive drugs or hypoglycemia induced by insulin [14].

Type B (Bizarre) Reactions: They are idiosyncratic, unpredictable, and not related to the pharmacologic actions of the drug. They affect susceptible individuals and are due to hypersensitivity reactions, e.g., penicillin anaphylaxis or severe cutaneous reactions like Stevens-Johnson Syndrome [15].

Type C (Chronic) Reactions: These are related to long-term drug use and involve dependence (opioids) or cumulative toxicity (renal damage from NSAIDs) [16].

Type D (Delayed) Reactions: These occur after prolonged exposure to drugs, often with teratogenic or carcinogenic effects, e.g., secondary malignancies secondary to chemotherapy [17].

Type E (End-of-Treatment) Reactions: These reactions occur after withdrawal from drugs, resulting in symptoms in line with opioid withdrawal syndrome [18].

Type F (Therapy Failure) Reactions: Failure reactions to therapy, which can occur as a result of drug interaction, resistance, or genetic difference in drug metabolism [19].

Impact of ADRs on Patient Safety and Healthcare Systems

ADRs significantly influence morbidity and mortality, causing increased hospitalization, prolonged treatment duration, and increased healthcare expenses. A major percentage of ADRs can be prevented, and hence efficient reporting and surveillance are critical in reducing their burden. In research, it has been shown that

hospitalization due to ADRs is 3% to 7% in industrialized nations and higher in resource-constrained environments [20]. Poor reporting of ADRs, clinician underreporting, and limitations in passive surveillance systems weaken effective pharmacovigilance [21]. Increasing the efficiency of reporting ADRs includes strengthening the passive as well as active surveillance systems. Passive surveillance by the use of spontaneous reporting systems (SRS) is afflicted by 90% underreporting worldwide. Improved awareness among healthcare professionals, electronic reporting platforms, and motivating incentives for ADR reporting can remarkably enhance data gathering. On the other hand, active surveillance with proactive strategies like prescription event monitoring and cohort event monitoring provides a more formalized approach to the identification of ADRs. Synergistic integration of both surveillance systems with the help of artificial intelligence (AI) and machine learning-based pharmacovigilance platforms can remarkably enhance the efficiency and accuracy of ADR identification [22].

2.2. Overview of Pharmacovigilance Organizations

Historical Background of Pharmacovigilance

The concept of pharmacovigilance emerged as a reaction to the high degree of concerns over drug safety during the past century. The thalidomide tragedy in the late 1950s and early 1960s, when thalidomide was prescribed to pregnant women and resulted in major congenital malformations [23], was one of the first and most significant events to highlight the need for monitoring drug safety. The tragedy served to enhance the need for strict drug safety regulations and led to the development of official pharmacovigilance systems worldwide. The Programme for International Drug Monitoring (PIDM) for the coordination of international drug safety evaluation efforts was initiated by the World Health Organization (WHO) in 1968. Pharmacovigilance has progressed dramatically since then, incorporating sophisticated technologies, regulatory requirements, and international collaboration to enhance the detection and prevention of adverse drug reactions (ADRs) [24].

The Role of National and International Regulatory Organizations

There are various regulatory agencies at national and international levels that are responsible for monitoring and enforcing pharmacovigilance regulation. These agencies ensure the safety, efficacy, and quality of drug products and public confidence in drug safety systems.

The World Health Organization (WHO) has a critical role in global pharmacovigilance via the Uppsala Monitoring Centre (UMC), which receives and collates ADR reports from member countries. WHO further offers technical assistance, guidelines, and tools for improved monitoring of drug safety globally [25].The United States Food and Drug Administration (FDA) oversees the pharmacovigilance activity in the nation through the Adverse Event Reporting System (FAERS) and the Sentinel Initiative employing electronic health records for enabling active surveillance. The FDA imposes strict post-marketing surveillance to enable the identification of rare and prolonged adverse drug reactions (ADRs) [26]. In Europe, the European Medicines Agency (EMA) runs the EudraVigilance system, the EU member states' centralized ADR database for live monitoring of drug safety. EMA works together with national competent authorities in a bid to achieve harmonized pharmacovigilance practice in Europe [27]. Pharmacovigilance in India is regulated by the Central Drugs Standard Control Organization (CDSCO) under the Pharmacovigilance Programme of India (PvPI). It aims to augment spontaneous reporting, improve monitoring of ADR, and increase public education on drug safety [28].

Other regulatory agencies, such as the Therapeutic Goods Administration (TGA) of Australia and Health Canada, play important roles ensuring compliance with pharmacovigilance within their respective countries as well.

Methods Employed in Pharmacovigilance

Pharmacovigilance applies a number of methods to detect and evaluate ADRs. These approaches are usually divided into passive and active surveillance methods.

Passive Surveillance: Passive surveillance, or spontaneous reporting, depends on physicians, patients, and pharmaceutical firms to report ADRs voluntarily to

regulatory authorities or pharmacovigilance centers. Spontaneous reporting programs, like the WHO's VigiBase and national databases FAERS and EudraVigilance, are the major sources of ADR information. Though critical, passive surveillance is hampered by underreporting, missing data, and reporting bias, which can restrict its usefulness in the identification of rare ADRs[29].

Active Surveillance Active surveillance means, in contrast, the natural process of monitoring for ADRs by routinely gathering and evaluating the information about it in healthcare facilities. Key active surveillance methods include:

Table 1: Key Methods of Active Surveillance in Pharmacovigilance

Method	Description	Key Advantages
Cohort Event Monitoring (CEM)	Follows a defined group of patients receiving a specific drug and records ADRs over time.	Systematic data collection, long-term safety insights.
Targeted Spontaneous Reporting (TSR)	Encourages healthcare providers to report ADRs related to specific drugs of interest.	Improves reporting rates for selected drugs, focuses on critical safety concerns.
Electronic Health Records (EHR) & Data Mining	Uses advanced data mining techniques on EHRs and claims databases for real-time ADR detection.	Enables large-scale analysis, enhances early signal detection.
Post-Marketing Surveillance (PMS) Studies	Includes Phase IV clinical trials to assess drug safety in real-world patient populations.	Detects rare and longterm ADRs, ensures ongoing safety monitoring.

AI and ML's integration in pharmacovigilance has enhanced the efficiency of ADR detection by far. AI algorithms consider a large amount of ADR data, decide on patterns and generate safety signals quicker compared to any conventional approach [33]. By increasing the effectiveness of active and passive reporting of ADRs, the desired outcome in pharmacovigilance can be achieved. Legal actions, raising awareness among the healthcare professionals and patients, increasing the usage of analytic techniques, and implementing the application of technology can also help in boosting ADR reporting and drug safety monitoring. The directions for future research are to achieve a better coordination and cooperation with other countries, other stakeholders as well as the integration of new technologies in the system of an efficient ADR identification [34].

2.3. Active vs. Passive Surveillance in ADR Reporting

Pharmacovigilance ADR surveillance is in two broad methods, which include active surveillance and passive surveillance. Passive systems involve the reporting of ADRs by healthcare professionals, patients as well as the companies responsible for the production and marketing of the drug spontaneously without being prompted. These reports are stored in the national and international pharmacovigilance databases including Food and Drug

Administration Adverse Event Reporting System (FAERS) and World Health Organisation's Global Individual Case Safety Report (WHO Vigibase) [35]. On the other hand active monitoring includes enhanced monitoring procedures of collecting data on ADRs. This method involves cohort event monitoring, registries and where the investigators go around looking for ADR details from certain populations, known as sentry site surveillances. Active surveillance, on the other hand, is different from passive one because it uses structured approach to gather the data on drug safety for herbals [36].

Advantages and Limitations of Each Method

Passive surveillance represents a commonly used ADR monitoring approach since it manages broad patient populations without requiring high costs and remains simple to execute. Through its spontaneous reporting system healthcare experts discover seldom-reported and unpredicted ADRs as confirmed. The system has a critical problem with reporting rate that diminishes its capacity to record accurate ADR frequencies. Not all possible adverse drug reactions get reported through passive monitoring due to non-mandatory reporting as well as reporting biases and incomplete data entry problems [37]. Complex patient groups belonging to active surveillance systems receive systematic analyses leading to more exact and thorough data about adverse drug reactions. A strengthened detection capability for ADR patterns emerges from active surveillance because it reduces underreporting errors while capturing data that passive systems typically miss. Active surveillance enables researchers to run purposeful pharmacovigilance studies that improve evaluation processes for risks and regulatory decision viability. The implementation of active surveillance encounters difficulties because of its high monetary and workforce requirements at large scale operations. Both methods fulfill essential roles in creating well-functioning pharmacovigilance systems yet passive surveillance provides a wider range of data sources than active surveillance [38]. The widespread nature of passive surveillance lets scientists collect many reports but active surveillance preserves accurate information by reducing reporting errors. A recommendation for better ADR reporting efficiency involves implementing both methods into a suitable collaborative framework. Enhancing the ADR surveillance system requires educational initiatives that develop healthcare professional critical ADR awareness as well as electronic health record usage and artificial intelligence-based real-time detection tools. Upcoming strategies need to optimize resource deployment alongside network expansion for active surveillance in order to strengthen pharmacovigilance operations [39].

3. PASSIVE SURVEILLANCE IN ADR REPORTING

3.1. Definition and Mechanism

ADR reporting systems maintain an essential position in pharmacovigilance since they protect drug safety and efficacy throughout actual usage situations. Healthcare professionals use passive surveillance to obtain ADR information through spontaneous reporting systems (SRS). The voluntary and mandatory reporting system functions through healthcare professional and patient submissions coupled with electronic health record examination [40].

The spontaneous reporting system functions as the primary component of passive surveillance through which healthcare providers and patients submit ADR reports without regulatory authority involvement. The practice of voluntary reporting prevails yet certain countries maintain obligatory ADR reporting regulations which force medical staff and pharmaceutical businesses to file reports with regulatory bodies including the FDA in the U.S. along with the EMA [41]. Reported data in passive surveillance networks originates from different sources including healthcare professionals and patients and electronic health record systems. Healthcare specialists who treat patients as well as pharmacists and nurses comprise the leading group of professionals who generate ADR reports because they encounter patients and medications in their work. The reporting of adverse drug reactions by patients has become significant because it lets healthcare professionals see drug side effect manifestations that prescription teams would not detect right away. EHRs function as a significant ADR data repository because they unite clinical notes with laboratory findings and medication histories to boost both signal discovery endeavors and pharmacovigilance programs [42].

3.2. Challenges in Passive Surveillance

The process of passive surveillance encounters various barriers which limit its effectiveness for ADR reporting activities. Among the most important obstacles stands underreporting and the insufficient knowledge about reporting among healthcare professionals. The reporting of Adverse Drug Reactions stands at a very low level

according to research which means marketed drugs show incomplete safety profiles. Multiple reasons combine to lead healthcare professionals toward underreporting including time limitations along with poor incentives and inadequate understanding about pharmacovigilance significance [43]. The accuracy of passive surveillance systems decreases due to imperfect and inaccurate data in ADR reports. Insufficient reporting details about patient profiles as well as drug amounts combined with treatment duration and final results renders it challenging for rule-enforcing bodies to confirm the cause-effect connections and exposed pharmaceutical security alerts. Quality improvements in reporting process need standardized guidelines together with better training for healthcare professionals to achieve better report accuracy and completeness [44]. The identification of both uncommon and time-delayed Adverse Drug Reactions poses an important challenge to detection efforts. Inactive surveillance depends on self-reported information which results in the prolonged elapse of time during which rare or delayed ADRs can go unnoticed. Unlike active surveillance, which proactively seeks ADR data through systematic monitoring, passive surveillance depends on spontaneous submissions, making it less effective in identifying long-term safety concerns associated with chronic medication use [45].Regulatory constraints and data management issues also impede the efficiency of passive ADR reporting. These barriers to effective ADR surveillance stem from variability in pharmacovigilance policies across various countries, a lack of harmonization in data collection formats, and limited interoperability among the different reporting systems. Also, due to resource constraints and archaic data management systems, regulatory agencies are often inundated with ADR reports that they are unable to timely process. Innovative fields such as artificial intelligence (AI) and big data analytics are potential tools that can improve data integration, signal detection, and regulatory decision-making in pharmacovigilance [46].

3.3. Strategies to Improve Passive Surveillance Efficiency

Enhancing Awareness Through Education and Training Programs

One of the primary reasons for underreporting in passive surveillance is a lack of awareness and knowledge about the importance of ADR reporting among healthcare

professionals and patients. Educational interventions and training programs can significantly enhance ADR reporting rates by fostering a culture of vigilance in clinical practice. Incorporating pharmacovigilance modules into medical, pharmacy, and nursing curricula can ensure that future healthcare professionals understand their role in ADR reporting from the early stages of their careers. Additionally, continuous professional development programs, workshops, and awareness campaigns can keep healthcare workers updated on regulatory requirements and the importance of ADR documentation [47].

Simplification of Reporting Procedures

The complexity of ADR reporting procedures often discourages healthcare professionals from submitting reports. Traditional paper-based reporting systems can be cumbersome, leading to delays and incomplete submissions. To enhance efficiency, user-friendly electronic reporting platforms and mobile applications have been introduced in various countries, allowing healthcare professionals and patients to submit ADR reports quickly and conveniently. These digital solutions offer structured templates, dropdown menus, and automated data validation, reducing errors and improving data completeness. Furthermore, integrating ADR reporting systems with electronic health records (EHR) can streamline the process, enabling seamless data entry without disrupting clinical workflows [48].

Incentives for Reporting ADRs

Granting motivation to report ADR can be used as an incentive measure to encourage more delegates to participate. Therefore, proposals such as giving the reporting healthcare professional either a financial incentive or CME credits, professional recognition have been put forward. In some nations, healthcare facilities have adopted incentives related to the performance that rewards departments that report high rates. Furthermore, rewarding and recognition of those HC professionals who are involved in the reporting on pharmacovigilance should be encouraged [49].

Strengthening Feedback Mechanisms to Encourage Reporting

A major problem that can be observed is that reporters are not informed of the outcome of the submission of reports which makes a lot of reporters lose interest. It is therefore important that there be an enhancement of feedback structures with regards to engagement. Frequency and timeliness of response to submitted reports, notification on causality evaluation, and periodic reporting of consolidated ADR data may help the healthcare professionals and patient understand that their report is important. Engaging the reporters for follow up discussion and providing them with an insight on some clinical effects of the reports can go along way in enhancing morale and willingness to participate in the study. Also, releasing of the periodic pharmacovigilance bulletins and safety alerts that describe and provide the information on the tendencies of ADR and actions of the regulating authorities can further underline the role of ADR in the context of patients' protection [50]. Program-wise, all educative programs should be fully adopted and supported; Reporting formalities should be put into the digital platform as much as possible; Monetary rewards should be offered for prompt and proper reports; and feedback systems should also be boosted. These strategies will in turn help enhance drug safety evaluation and thus patients' wellbeing in different parts of the globe [51].

4. ACTIVE SURVEILLANCE IN ADR REPORTING

4.1. Definition and Mechanism

Pharmacovigilance plays an important role in implementing ADR and other risks for medicinal products relevant for patient safety. The active surveillance is a more comprehensive and direct proactive method in comparison with passive surveillance which means collecting and investigating ADR data without requiring specific reports from the users. Active surveillance is more efficient in detecting ADRs due to the various methodologies used in carrying out the survey. One major type of design is the cohort studies that entail the identification of a specific population which has been under the use of a certain drug and the rate of ADRs observed after some time. This technique helps in making temporal relationship between the use of the drug and

occurrence of ADR. Similarly to TTS, case control studies focus on the difference between patients who have had an ADR and the patients who have not had an ADR but help in the identification of risk factors and predisposing conditions to ADRs [53].

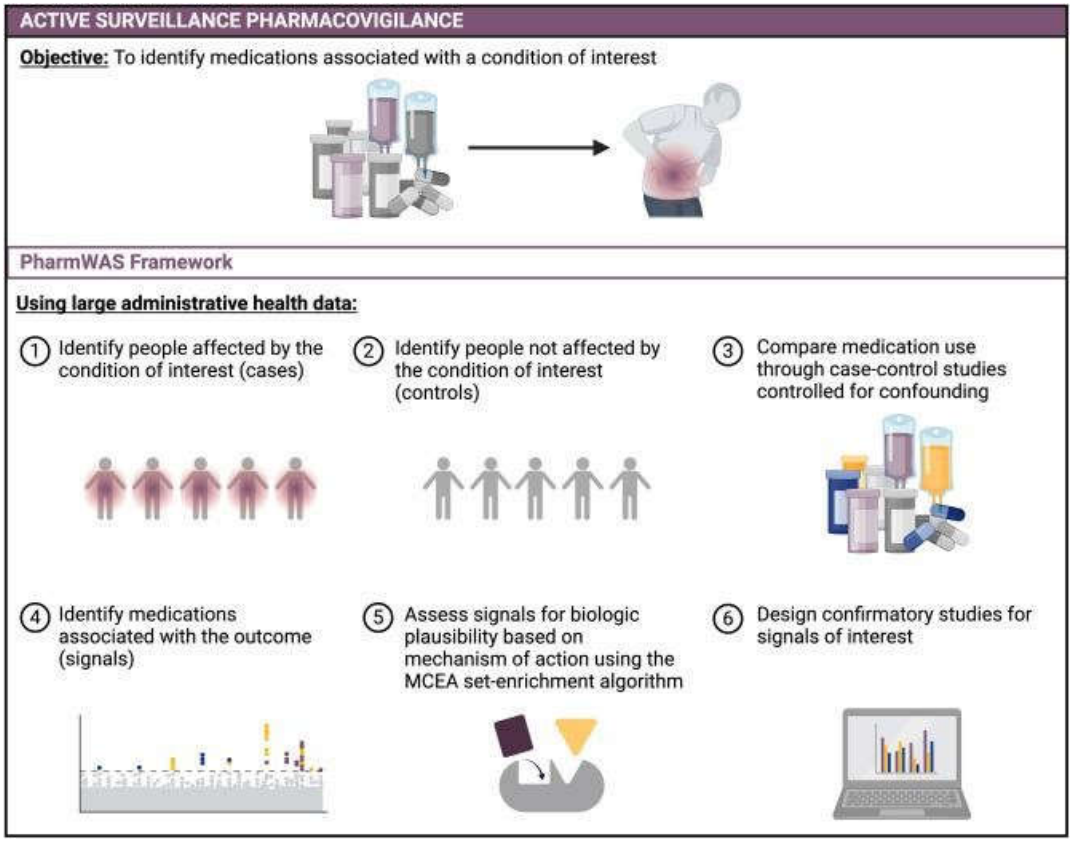

Figure 2. Active surveillance in adr reporting

Another significant method is prescription event monitoring (PEM), which evaluates ADRs by analyzing prescription records and correlating them with reported adverse events. This technique is particularly beneficial in post-marketing surveillance, where large-scale prescription data provide insights into real-world drug safety. A second active surveillance method is sentinel site monitoring which involves identifying some few health centers or hospitals where ADRs are documented in a standardized manner from the identified sites. This method increases the ADR detection comprehensiveness by offering clinical information from the selected sites [54].Utilizing EHRs and large healthcare databases improves on active surveillance. The data inside EHRs can also be useful for real-time ADR detection through producing the data from patient

investigations, laboratory results, and observations printed within the system. sophisticated signal detection based on pattern recognition applied on such databases can facilitate improved pharmacovigilance efficiency through the use of artificial intelligence in form of algorithms. Such technologies help to increase the efficiency of ADR recognition to minimize potential dangers to patients' safety and promote the production of adequate regulation decisions. Another perspective of drug safety monitoring in active surveillance is based on different methods of ADR detection in which cohort comparisons, case control facilities, PEM and sentinel site reporting studies can be used. Similarly, by combining EHRs and data analytics, ADR detection becomes even more efficient since the tools система to be more proactive than reactive on drug safety matters [55].

4.2. Challenges in Active Surveillance

Nevertheless, beside the benefits mentioned above, which make active surveillance improve the efficiency of ADR reporting, several challenges exist that do not allow active surveillance to expand and become integrated into healthcare systems massively. These are mainly in the areas of finance, ethic, technical support, infrastructure and systemic integration. Overcoming these barriers is key when improving the ADR reporting system and developing and enhancing the pharmacovigilance systems in different countries. There is always a concern that active surveillance patient is costlier, time consuming and labor intensive approach than passive. Whereas passive surveillance relies primarily on reporting submitted by professionals in the field and patients, active surveillance entails the use of staffs, data capturing systems, and constant monitoring. There is a need to hire more pharmacovigilance staff, increasing use of data analytics tools, and establishing and following up systems for patients also increases operation cost. Small health-care systems especially from LMIC cannot afford to have effective active surveillance systems and therefore there are variations in efficiency of ADR reporting in different regions across the world [56].

This is in a context of ethical issues that are likely to crop up when it comes to monitoring of patients' data. Active surveillance entails routine gathering of health

information about the patients, issues of concern arising from this process are privacy, confidentiality, and consent. It is pertinent to follow these ethical standard and legal obligation like GDPR of European Union or HIPAA of USA to maintain the trustworthiness of the patient. One of the key non-treatment related consideration is that there might be an ethical conflict when trying to collect all the necessary data on ADRs while at the same time" Ethical control measures and policies to prevent risks resulting from violation of data privacy are highly essential [57]. Another question is the necessity of having sophisticated technological support which is another factor that poses a challenge in active surveillance. Currently, pharmacovigilance systems need to be compatible with EHR databases, real-time technology, and reporting applications to improve the efficiency of identifying ADRs. Nevertheless, various health care centers especially in the developing world, have limited system interface and database compatibility with these elaborate systems. Utilizing AI and ML algorithms, presence of ADRs have been closely monitored and the results achieved show that new capabilities for surveillance have been introduced to the industry. However, some of the key constraints toward the adoption of these technologies include high cost to be incurred, as well as the requirement for professionals for data management and analysis [58].Two main factors exist concerning the active surveillance; first, the cost of implementing the technology is prohibitively expensive due to infrastructure development problems, and second, integration of the active surveillance with present day health care systems is challenging. Most hospitals have developed their feeble data structures that are not very compatible with others as they are not integrated. Lack of standard reporting formats embraced across various institutions and high variability in ADR data acquisition pose a great challenge to data exchange and evaluation.

The regulatory agencies' engagement of active surveillance programs can be made easier by setting up of standardized reporting system, RACR and other reporting guidelines; cooperation between the two reporting systems with other pharmacovigilance databases and other reporting systems existing; and by increasing cooperation and coordination between the various reporting agencies and healthcare players. To eliminate these barriers, governments, regulatory authorities,

pharmaceutical firms and health care facilities must collaborate towards developing sound methods for monitoring ADRs [59].Hence for better ADR reporting efficiency through active surveillance, the government, regulatory Authorities, pharmaceutical firms, and healthcare facilities should find ways on how to improve the process. Although active surveillance is more advantageous than passive reporting in its high sensitivity, prompt signal detection, and almost zero inaccuracy, there are some drawbacks that ألفصssociated with their implementation. Active pharmacovigilance can be enhanced only if the essential barriers such as financial limitations, ethical issues, technical shortcomings, and the problem of integrated working are tackled. The following strategies can be used to overcome such barriers: There is a tremendous potential in investing in digital health technologies that can increase the competencies of different stakeholders such as patients and clinicians in delivering, accessing, paying for, and organizing health care. Both AI integration into the surveillance processes and the use of the blockchain innovative technology will improve the existing ADR reporting and enhance the International pharmacovigilance systems significantly in the future. If these challenges are to be dealt with collectively, then the approach to monitoring drug safety would be more robust, efficient and understanding of the patient's perspective required for the same [60].

4.3. Strategies to Improve Active Surveillance Efficiency

4.3.1. Leveraging Artificial Intelligence and Big Data Analytics

The advanced technologies such as artificial intelligence and big data analytics have changed the field of pharmacovigilance and improved the detection/analysis of and prediction for ADRs. Using AI technology, algorithms can track massive data in health care, and it is possible to find out ADR patterns, which will be difficult to recognize in usual surveillance. The use of EHRs, SMM, and clinical trials can be effectively utilized by the machine learning algorithms for the identification of novel ADR signals. Moreover, NLP can help identify ADR from the unstructured documentation, as well as patient feedback. The use of AI in relatively integrating with pharmacovigilance databases greatly enhances the speed of the generation of signals and the ability to respond to drug hazards [61].

4.3.2. Establishing Real-Time Monitoring Systems

Electronic systems provide a dynamic approach to carrying out of ADR monitoring, which allows for quick identification and further investigation of the event. Through the use of realtime monitoring, monitoring, ADRs occur within hospitals can immediately be fed into hospital information systems thus, eliminating reporting latency and increasing the accuracy of data. According to the research study, there are also advantages of having ADR reporting that is done using systems that feed into national pharmacovigilance databases since it increases the reporting efficiency and reduces possibilities of human errors. Further, they allow healthcare institutions, regulatory bodies, and research organizations to share data regarding ADRs easily and, thus, improve control and evaluation [62].

4.3.3. Encouraging Hospital-Based Pharmacovigilance Centers

The hospital based pharmacovigilance centres are strategic centres for identification and reporting of ADRs. The objective for having formalized hospital pharmacovigilance offices is to maintain constant information gathering, ranch and distribution. Such centres help in establishing a direct communication link between the healthcare professionals and the regulatory authorities of a country to enhance the reporting and completion of ADR. Pharmacovigilance training sessions or workshops contribute towards improving the rate of reporting of ADR by increasing awareness among the health care professionals. Thirdly, integration of Pharmacovigilance training in the academic programs of both medicine and Pharmacy helps to create awareness of ADR among the future members of the health professions [63].

4.3.4. Public-Private Collaborations for Improved Funding and Implementation

Intensive cooperation with pharmaceutical companies is beneficial for authorities to boost the active surveillance outcomes. Government and private organizations offer the sources of funding, structure or framework and technical knowhow in monitoring ADR. The role of pharmaceutical companies is to provide additional information and post marketing surveillance data as well as to fund pharmacovigilance research studies

to in improvement of ADR identifications. Additionally the partnership of regulatory bodies with technological companies can help in enhancing the use of innovative applications and tools for monitoring ADRs and preparing instant reports on the same. Global pharmacovigilance networks help to share the practices, thus creating an internationally coherent system of ADR monitoring [64].Ensuring an active reporting of ADRs involves the use of technology, time-sensitive systems, hospital pharmacovigilance centers, as well as interactions of patients, healthcare professionals, and manufacturers. Machine learning helps in the detection of signals, round-the-clock surveillance guarantees fast identification of ADRs, and dedicated facilities for data gathering in the hospitals improve the systematic flow. Parionets is an interactive forum of pharmacovigilance professionals and is open for public-private partnerships to improve its programs and activities.

Through the employment of the above approaches, the pharmacovigilance system can enhance ADR reporting standards and thus enhance on patient safety and drug control [65].

5. INTEGRATION OF ACTIVE AND PASSIVE SURVEILLANCE FOR BETTER ADR REPORTING

5.1. Need for a Hybrid Model

The state of the art of active and passive surveillance systems with a view to establishing how their combination is important in improving the reporting of ADR. Cohort event monitoring and selective clinical investigations on patients are used in active surveillance that detects all the ADRs. On the other hand, passive system focuses on using reporting systems in which reporting is done by care givers or even the patients themselves. The utilization of some features of the two systems also poses some benefits, making the hybrid model a stronger system of pharmacovigilance. The other component of the hybrid model is shared databases that will ease the sharing of data between health care institution, regulatory bodies and pharmaceutical firms. These types of databases can assist in the real time evaluation of ADRs and also bring development into the signal detection systems. Possible applications of EHRs together

with AI analytics include detection of patterns that are difficult to note with conventional reporting systems-such; is the case with a hybrid model that also advocates for a marked and enhanced prevention of ADRs. Comparing to passive surveillance, active surveillance offers more control over data gathering due to lesser chances of underestimating the magnitude of disease as is usually seen with passive surveillance systems. However, passive surveillance is a better technique in that it reveals not only the short-term and event-specific ADRs that are shown in controlled clinical trials but also such infrequent ADRs as those that last over the long term. By connecting these strategies, pharmacovigilance systems could be effective in the identification of the possible safety issues of a drug and consequently, quick regulatory measures which would protect the lives of patients [68].

5.2. Case Studies and Successful Implementations

By 2000, many states have adopted mixed methods of pharmacovigilance comprising of both the active and passive systems. An example of such system in the United States is the Sentinel Initiative that was started by the Food and Drug Administration (FDA). Sentinel uses EHR data, insurance claims and clinical trial data and is a distributed system that actively in identifying ADRs, the patient enters the system enters the EHR data base and a check is made for any past exposure to the medication in question and if there has been then ongoing monitoring kicks in for any ADRs. This system has enhanced the rate at which drug related safety concerns can be detected and it has assisted the regulators. The same applies to the EU, where EudraVigilance acts as a system of pharmacovigilance that involved both spontaneously submitted reports and clinical observations. It has also helped in enhancing the effectiveness of the ADR signal detection and the subsequent regulatory actions for the protection of drug safety [69]. In the developed country, active and passive surveillance systems have been identified to be important for enhancing the reporting of ADRs in the developing country. For instance, in India, the Pharmacovigilance Programme of India (PvPI) has gradually grown by encompassing the commencing active pharmovigilance tools like Prescription Event Monitoring and Targeted Spontaneous Reporting. Deriving from the findings of the study it can be concluded that the above implementations that have

led to the improvement of ADR reporting rates as well as contributing to the enhancement of safety in health care . AI, machine learning, and big data analytics have also enhanced pharmacovigilance across the world by helping in the monitoring of ADR this has made it easier and accurate [71].

5.3. Recommendations for Policy Makers and Regulatory Agencies

Therefore, for the improvement in ADR reporting, the policymakers and the regulatory agencies have to implement more robust measures which improve the pharmacovigilance system. One of the considerations proposed in the recommendations is the creation of sound regulatory guidelines that will make it compulsory for firms to report ADRs as part of assessing the safety of drugs. Increasing the rigidity of laws that govern the pharmaceutical companies in regards to the post marketing surveillance can help in strengthening drug safety even further. Another important area here is promotion of RWE. Interactions are often recorded in traditional clinical trials, specifically, in their outcome measurement, because of the restrictive environment and select patient samples. Thus, it would be useful to involve RWE from hospitals, outpatient clinics, and community pharmacy practice for a better evaluation of the safety of a given drug. There are some recommendations, which have to be followed by policymakers to enhance the collaboration between academic institutions, healthcare, and regulatory organizations to set up the centralized database for RWE collection [72].

To this end, there is a need for creation of a culture of pharmacovigilance amongst the healthcare professionals to facilitate enhanced reporting of ADRs. Regular training programs should be conducted to increase involvement of the healthcare professionals in pharmacovigilance activities. Thirdly, the concept of redesigning ADR reporting therefore should incorporate friendly reporting technology in digital form such as the online platforms and mobile applications to increase reporting among practitioners as well as patients. The general conclusion then is that the active and passive surveillance, use of technological developments and culture change all contribute towards increasing the efficiency of ADR reporting thus increasing patient safety and public health [73].

6. TECHNOLOGICAL INNOVATIONS IN ADR REPORTING

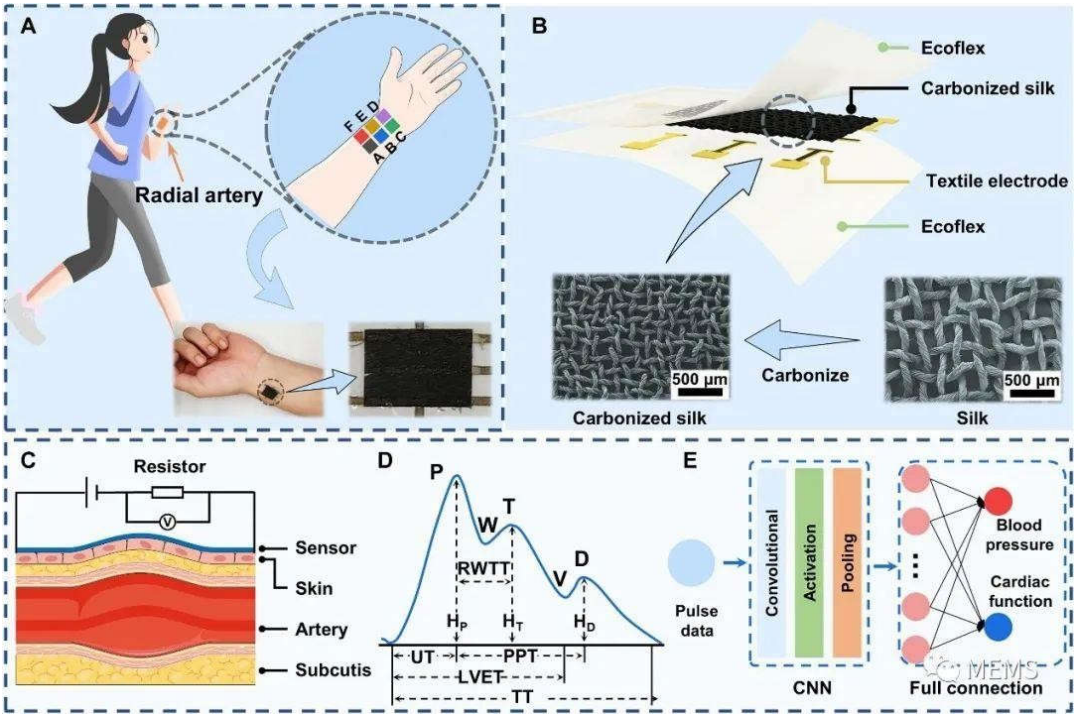

Figure 3. Biometric Data Integration in wearable devices for continuous patient monitoring collects

Thus, the utilization of contemporary technologies in the field of pharmacovigilance has brought the development about a long way. There has also been an improvement in the reporting of Adverse Drug Reaction (ADR) through active and passive reporting systems through the commendable use of technology such as AI and ML. These techniques have the ability to enhance the detection, analysis, and reporting of ADR cases which are the main aspects in pharmacovigilance. Thus, integrating AI and NLP coupled with automation of ADR reporting systems for true pharmacovigilance means better proactive development with higher precision in process accuracy in real-time. The employment of these technologies has put to an end certain factors that affect conventional reporting systems for instance under reporting, delayed detection and poor data analysis.

6.1. Role of Artificial Intelligence and Machine Learning

Predictive Analytics for ADR Detection

Predictive analytics, fueled by artificial intelligence (AI) and machine learning (ML), is essential in the early identification of adverse drug reactions (ADRs) before they escalate into significant public health issues. Machine learning algorithms, trained on large amounts of pharmacovigilance data, can sift through large amounts of structured and unstructured data to detect patterns and associations that can predict potential ADRs. By using historical ADR data, ML algorithms can calculate the probability of an adverse event linked to a particular drug, thereby allowing regulatory agencies and healthcare professionals to act proactively. One of the strengths of predictive analytics in pharmacovigilance is that it can detect rare or unknown ADRs. Conventional reporting systems are based on voluntary reporting of adverse events by healthcare providers and patients, which often results in underreporting and delayed risk detection. By contrast, AI-based systems continuously monitor electronic health records
(EHRs), social media, and scientific literature to detect potential ADR signals in real-time. These systems employ sophisticated algorithms to assign risk scores to suspected ADRs, thereby ensuring that high-priority cases are acted upon in a timely manner. Moreover, deep learning algorithms can potentially improve the specificity and sensitivity of ADR detection, thereby minimizing false positives and allowing accurate case identification [74].

Natural Language Processing for ADR Case Identification

Natural Language Processing (NLP) has become an important tool in the pharmacovigilance field, as it enhances the identification of adverse drug reactions (ADRs) by computerizing the extraction of pertinent information from various textual data sources. Because of the enormous quantity of unstructured data found in clinical notes, medical literature, patient forums, and social media, NLP algorithms are programmed to read and process textual data, thereby enabling the efficient identification of potential ADR cases. NLP application in reporting ADRs has reduced

the workload by gaining much in terms of the speed of case processing. Conventional pharmacovigilance procedures typically involve time-consuming activities involving manual review of medical records, which are not only labor-intensive but also errorprone. NLP approaches, including named entity recognition (NER) and sentiment analysis, enable the automated detection of drug-event associations from text, supporting an increased speed of identification of ADR cases with high accuracy. Additionally, NLP models are constantly updated through supervised and unsupervised learning processes that enhance their capacity to identify actual ADR signals and ignore noise drug mentions. One of the most promising applications of NLP in the field of pharmacovigilance is its use in extracting information from social media and online patient forums for ADR reporting. Patients report their experiences with drugs on the internet, hence providing an important source of real-world evidence that can supplement traditional reporting systems [75]. By monitoring patientreported outcomes in online forums, NLP algorithms can identify emerging safety issues that may not be easily apparent in clinical trial data. Additionally, NLP-powered chatbots have been engineered to facilitate easier ADR reporting by guiding patients through questionnaires, enabling comprehensive and consistent case documentation.NLP and predictive analytics, coupled with AI and ML, have significantly improved the effectiveness of ADR reporting in active and passive surveillance systems. These technologies enable proactive surveillance, realtime detection, and automated case identification, addressing most of the issues inherent in conventional pharmacovigilance approaches. Predictive analytics enables early detection of potential ADRs, allowing regulatory agencies to implement timely interventions, while NLP enables the efficient extraction of ADR-related information from vast textual databases. As technology continues to evolve, future developments in AI and ML are expected to improve the accuracy and efficacy of pharmacovigilance, ultimately translating into improved drug safety and patient outcomes [76].

6.2. Blockchain Technology for Secure and Transparent Reporting

Blockchain technology has attracted considerable interest in the healthcare industry, especially in the area of pharmacovigilance, because of its intrinsic properties of

decentralization, immutability, and transparency. It is based on a distributed ledger system where each transaction, such as ADR reports, is stored in a secure and tamper-evident form. Blockchain use in ADR reporting has a number of benefits and some drawbacks that must be overcome for successful integration into current PV systems [77].

Advantages in Data Security and Auditability

One of the primary advantages of blockchain technology in ADR reporting is increased data security. PV databases in traditional systems are prone to data breaches, unauthorized tampering, and data loss. Blockchain solves these issues by encrypting ADR data and spreading it across nodes, minimizing the likelihood of unauthorized tampering. Every transaction in the blockchain network is time-stamped and encrypted, making ADR reports immutable and verifiable.

In addition, blockchain improves traceability by providing an auditable record of ADR information, enabling regulatory bodies, healthcare providers, and pharmaceutical firms to track the origin, changes, and movement of ADR reports. This aspect is especially helpful in avoiding data tampering and regulatory compliance. Blockchain transparency enables stakeholders' trust, resulting in higher ADR reporting rates [78].

Implementation Challenges and Potential Solutions

Though it has its benefits, the application of blockchain technology in PV systems has some disadvantages. One of the main disadvantages is the implementation complexity. Blockchain needs high computational power and knowledge of distributed ledger technology, which may restrict its application in resource-poor environments. Moreover, interoperability with current PV databases and regulatory systems is required for efficient data exchange. Standardization of data formats and coordination among stakeholders are required to overcome these challenges.Another challenge is the possibility of increased data processing time due to the decentralized nature of blockchain. Because every transaction must be verified by several nodes, the time to store and fetch ADR reports may be higher than in conventional centralized databases. Optimization of consensus mechanisms, such as the use of permissioned blockchain

models, can overcome this challenge and enhance system efficiency [79]. In addition, regulatory compliance and data privacy issues need to be addressed. While blockchain improves data security, data immutability can be challenging to adhere to regulations like the General Data Protection Regulation (GDPR), which requires the right to erasure. Hybrid blockchain architectures, where sensitive information are kept off-chain with access control, can be a practical solution to achieve balance between security and regulatory needs.All in all, blockchain technology has tremendous potential to enhance the efficiency of ADR reporting by providing data integrity, transparency, and security. Nevertheless, the challenges presented by it need to be addressed through strategic implementation and regulatory cooperation to enable its successful integration in pharmacovigilance [80].

6.3. Mobile Solutions and Applications in Digital Health

Advantages of Mobile-Enabled ADR Reporting

Mobile apps have revolutionized the reporting of adverse drug reactions (ADRs) by providing a straightforward, real-time, and accessible platform for healthcare professionals and patients. The ease of mobile-based reporting systems allows for the quick submission of ADRs, thus ensuring the timeliness of data collection. Mobile apps can also be used with artificial intelligence (AI) algorithms to detect and analyze trends in ADRs, thus enabling predictive insights to inform the monitoring of drug safety. The major advantage of mobile-based ADR reporting is the potential to minimize underreporting, which is a major hindrance in conventional pharmacovigilance. A number of healthcare professionals and patients are hesitant to report ADRs due to the time-consuming and complex nature of conventional reporting systems. Mobile apps make the process easy by offering structured forms, drop-down menus, and guided submission processes to reduce the burden of reports. The apps can also be designed to incorporate automated reminders and alerts, thus encouraging frequent reporting of ADRs among users. From a regulatory perspective, mobile-based ADR reporting allows for effective communication between reporters and pharmacovigilance centers. Data can be automatically transferred to national and international regulatory databases, thus ensuring quick signal detection and

intervention where necessary. Additionally, these platforms can be designed to support multilingual reporting, thus encouraging global participation and the inclusion of heterogeneous patient populations in ADR surveillance [81].

Examples of Successful Pharmacovigilance Apps

Several mobile apps have been effectively leveraged in the pharmacovigilance process, which demonstrates their potential to enhance the process of reporting adverse drug reactions (ADRs). For instance, the World Health Organization's (WHO) VigiAccess is an internet-based system that provides users with access to global ADR data, whereas other applications like the FDA's MedWatch and the UK's Yellow Card Scheme provide effective ADR reporting services. The Med Safety application, developed by the Medicines and Healthcare products Regulatory Agency (MHRA) in collaboration with the WHO, has been widely used in several countries. This application provides healthcare professionals and patients with the facility to report suspected ADRs directly to national pharmacovigilance authorities. In addition, the Med Safety application utilizes real-time notification processes that confirm instant feedback on drug safety warnings and regulatory messages. Another interesting example is the ADR Reporting application developed by the Indian Pharmacopoeia Commission (IPC), which is a part of India's Pharmacovigilance Programme. This application provides users with the facility to report ADRs in several languages along with educational material aimed at enhancing knowledge on pharmacovigilance techniques. These impressive implementations show the potential of mobile technology in streamlining ADR reporting processes and enhancing pharmacovigilance systems globally [82].

6.4. Social Media's Role in ADR Reporting

Mining Social Media for Patient-Reported ADRs

The spread of digital communication has brought about the rise of social media sites as valuable sources of information on pharmacovigilance. Patients share their experience with drugs on sites like Twitter, Facebook, Reddit, and health forums, providing real-life information on drug safety concerns. Patient-generated data can be

utilized to supplement traditional adverse drug reaction (ADR) reporting systems, allowing for the early detection of safety signals. Pharmacovigilance scientists use natural language processing (NLP) and machine learning methods to extract relevant data from social media information on potential ADRs. Analyzing comments posted by users, scientists are able to identify emerging drug safety concerns that would remain unknown otherwise. This method is particularly useful to identify ADRs associated with over-the-counter (OTC) drugs, herbal supplements, and newly introduced drugs, where traditional reporting systems are not available. One of the significant benefits of social media mining is its ability to capture real-time patient experience, thereby providing an unmediated representation of the incidence of ADRs. Compared to traditional clinical trials or formal ADR reporting systems, social media posts provide a snapshot of drug use on a day-today basis among heterogeneous populations. This extends the reach of pharmacovigilance by tapping information from non-traditional sources, such as those patients who do not interact with healthcare providers on a regular basis [83].

Ethical Issues and Validity of Data

Though social media provides a promising platform for monitoring ADRs, it is also plagued with serious ethical and data reliability concerns. The foremost concern is patient privacy and data protection. Social media mining of ADR-related data should adhere to ethical principles that respect user confidentiality but allow researchers to extract useful pharmacovigilance information. The second concern is the accuracy and reliability of social media-collected information. Unlike reports obtained through official channels of pharmacovigilance reporting, social media postings may lack essential clinical details, and thus reported ADRs cannot be verified. Furthermore, the occurrence of misinformation, duplicate entries, and subjective views can pollute data quality. To alleviate these concerns, researchers employ advanced AIbased filtering techniques to remove true ADR reports from noise and irrelevant content [84]. Despite such challenges, regulatory agencies and pharmaceutical companies are increasingly considering the integration of social media analytics into pharmacovigilance systems. The European Medicines Agency (EMA) and the United States Food and Drug

Administration (FDA) have initiated pilot projects to establish the feasibility of integrating social media data into adverse drug reaction (ADR) signal detection systems. The initiative reflects the growing acceptance of digital media as powerful tools in the development of pharmacovigilance. Integration of technological innovations in ADR reporting has significantly enhanced the effectiveness of pharmacovigilance systems. Mobile health apps and digital health platforms provide a systematic, convenient, and efficient platform for reporting ADRs and thereby reducing underreporting and regulatory response time. At the same time, social media analytics also offer a novel way of collecting patient-reported ADRs to complement conventional surveillance methodology. However, ethical and reliability concerns regarding social media information mean that rigorous validation processes must be applied. In the coming years, the intersevity of mobile technology, social media analytics, and artificial intelligence-based pharmacovigilance solutions will become a critical factor in enhancing global drug safety surveillance [85].

CONCLUSION

Adverse Drug Reaction (ADR) reporting is a part of pharmacovigilance that ensures drug safety and improves public health outcomes. This study captures the strengths and weaknesses of active and passive surveillance systems. Active surveillance is beneficial in increasing ADR detection by active monitoring, whereas passive surveillance is the cornerstone of worldwide pharmacovigilance due to its universal reach. Underreporting and inaccuracy of data in passive surveillance are tremendous challenges. Future innovations in ADR reporting must integrate digital health technologies, artificial intelligence, and real-time data analysis to improve detection efficiency. Patient empowerment with mobile health applications and electronic health records will bridge reporting gaps. In addition, ADR reporting frameworks for developing countries will improve data comparability and strengthen global pharmacovigilance networks. Continued improvements in ADR reporting must involve collective efforts from healthcare professionals, regulatory authorities, the pharmaceutical industry, and researchers. Capacity-building exercises, training workshops, and advocacy campaigns can be employed to strengthen ADR reporting

culture among healthcare professionals. Increased global collaborations, including collaborative sharing of ADR data between regulatory agencies, will facilitate quicker identification of safety signals and improve drug risk assessment strategies further. A call for action is imperative to bring about tangible change in pharmacovigilance. Researchers must work on creating state-of-the-art ADR detection models, healthcare professionals must actively participate in ADR reporting, and policymakers must implement regulatory policies to create a streamlined and transparent reporting process. By incorporating a pharmacovigilance culture, we can significantly improve drug safety and public health worldwide.

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