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EFFECT OF DIRECT INTEGRATION OF LABORATORY TESTING AND REAL-TIME PATIENT DATA MANAGEMENT ON PRECISION DOSING OF HIGH-RISK PATIENTS IN AN ASTHMA CLINIC

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Abstract

Background: Precision dosing is critical for high-risk patients in tertiary hospitals as any delays in intervention may result in negative outcomes. The goal of this research is to assess how the incorporation of real-time laboratory data into clinical workflows affects drug related side effects as well as patient care in terms of the achievement of suitable therapeutic targets.

Methods: For the purpose of this retrospective observational study, we have included 500 patients requiring accurate dosing of their medications, at a tertiary hospital. Data pertaining to clinical outcomes, time relating to dose adjustment, occurrence of adverse drug reactions and achievement of therapeutic target were collected before and after the introduction of the real time laboratory data integration approach.

Results: Incorporation of real-time lab data helped vancomycin patients achieve therapeutic targeting of 85% from an outset of 55% while warfarin user's achievement improved from 60% to 88%. Adverse drug reactions, including nephrotoxicity and bleeding, decreased from 25% to 10% and 20% to 8%, respectively. The time to dose adjustment also fell from 4.8 ± 2.1 hours to 1.2 ± 0.8 hours. Other metrics related to patient outcome also improved with a decrease in length of hospital stay by 2 days as well as mortality declining from 12% to 8%.

Conclusion: Automated integration of real-time laboratory data stream substantially improves dosing accuracy, decreases negative events and achieves better clinical results in monitored patients in real time. These results demonstrate the need for now short wave systems to be deployed in tertiary hospitals in order to improve the quality of patient services and working efficiency.

Keywords: Individual drug administration, real-time laboratory and clinical data stream, monitored patients/shock patients, brain Infections hospital, therapeutic drug monitoring, drug side effects, clinical outcomes.

Introduction

The application of real-time laboratory results in clinical functioning has resulted in an enormous alteration in patient management, with a focus on high risk patients. In personalized medicine, precision dosing stands out as one of its key aspects with the accuracy of timing when laboratory data becomes available being critical to avoiding unwanted reactions and maximizing therapeutic benefit. Tertiary hospitals have a higher degree of complexity and hence medication errors have higher costs and therefore require data driven interventions (Bae et al, 2012; Chua et al, 2021).

Chronic kidney disease, cancer and sepsis are among the most life-threatening conditions that can cause toxicity and have diverse pharmaco-kinetic receptors. For patients in an advanced stage of illness, the use of predictive dosage models that depend solely on historical information poses problems since their health status could change quickly. Technological developments in the area of medical informatics have provided a means to update clinical decision support systems with rolling information like current renal activity levels and liver enzyme levels (Koch et al, 2022; Koyner et al, 2018).

It has been established that integrating laboratory data into the dosing algorithms does not only ensure safety of the drug, but it also enhances the clinical outcomes. It has been shown by Chalasani et al, 2023 & Altieri Dunn et al 2021 that with the use of antibiotics and anticoagulants, real-time feeds with laboratory data significantly cut down the adverse events and the duration of a patient's stay in hospital through therapeutic drug monitoring. Furthermore, the implementation of machine learning models has proven to augment with predictive modeling algorithms that take into account factors lab data feeds (Simonov et al 2018 and Komorowski et al 2019 highlighted this).

Most of these improvements made in therapeutic applications are however hampered by resistance of clinicians and other overlap issues. Causation of these problems is very important to understand for optimal usage of clinical informatics in pharmacy to support precision dosing (Waitman et al 2011, Lim et al 2022). The objective of this paper is to assess the clinician's perspectives of the use of laboratory data in assisting with precision dosing within a tertiary hospital.

Literature review

The Role of Real-Time Laboratory Data in Precision Dosing

Over the past half century, science and technology have advanced greatly and now expect the quick integration of lab data with other healthcare information systems. Dosing adjustments can be made "on the fly" based on a patient's condition that is being monitored in real-time. Clinicians do not have to wait until lab tests are completed. Whereas traditional models rely on static lab values or share a historical perspective on dosing, now it is easier to respond to changes in critical renal function parameters or liver Enzymes (Bae et al., 2012; Chua et al., 2021). This applies to high risk groups where even physiological disturbances or being critically ill changes the kinetics of drug metabolism and excretion (Komorowski et al., 2018).

In antibiotic therapy, for example, therapeutic drug monitoring (TDM) has been shown to decrease toxicity and increase efficacy in critically ill patients. Koch et al. (2022) sought to highlight the incorporation of proper bioanalytical methods and real realtime lab monitoring in order to achieve the user-optimized drug levels of sepsis patients. Other instances where real time data integration has worked to the advantage of patients are during anticoagulant therapy in which dosage was repeatedly adjusted in real time according to the coagulation profiles of patients in order to reduce the risk of bleeding (Altieri Dunn et al., 2021).

2. Impact on High-Risk Populations

Due to the changes in pharmacokinetics, patients from the high-risk cohorts such as those with chronic kidney disease (CKD), sepsis or oncaemic patients, are at a greater risk of having adverse drug reactions. However, real-time monitoring has shown to considerably reduce those risks. For instance, Simonov et al (2019) developed a predictive analytics risk model that utilized real-time lab information in order to identify patients who are at a risk of suffering from acute kidney injury (AKI), thus enabling timely intervention. Another example would be the integrated laboratory dashboards that have been used for patients enrolled on nephrotoxic medications which have been found to reduce AKI incidence (Koyner et al, 2018).

In the field of Oncology, chemotherapy toxicity has been reduced by making alteration of doses after liver function tests are performed. A review provided by Chalasani et al who were in collaboration

with many authors (2023) explains the role of pharmacy health and laboratory services in the control of dosing that have been specifically designed for high risk oncology patients.

3. Technological Innovations Supporting Integration

Applications of machine learning techniques as well as the recent developments in health informatics have improved the utilization of active laboratory results. As it is reported by Lim et al. (2022), the integration of ML algorithms to EHRs enables real time analysis of critical laboratory data such as creatinine levels and drug plasma concentrations to provide real-time evidence based dosing solutions. A study that was conducted by Komorowski et al. (2018) confirmed the efficacy of employing decision support systems through AI in reducing mortality rates during sepsis management by providing timely diagnosis and treatment.

Technological solutions also facilitate quick availability of laboratory information to pharmacists and clinicians. Automated monitoring systems have been effective in preventing and notifying providers' attention to critical lab results with the aim of correcting alterations in therapeutic doses (Bae et al., 2012; Waitman et al., 2011). Such systems not only enhance patient safety, but also create a conducive environment in tertiary hospitals where swift decision-making on patients is the order of the day.

4. **Challenges in Implementation**

While real-time laboratory data has the potential to enhance clinical practice, the incorporation of laboratory data in clinical practice meets a myriad of barriers. For instance, Lim et al. (2022) noted that interoperability challenges between EHRs systems and laboratory information systems hamper the progression of seamless data exchange. Most importantly, ensuring accuracy and having timely reports still remain strong barriers towards widespread integration of these systems (Chua et al., 2021).

The implementation of these systems need to take into consideration the clinician's level of comfort with change. The first one is that technologies and in particular automated alert systems were implemented in a trial study (Altieri Dunn et al., 2021) notwithstanding the impact of their overuse which was alert fatigue for the providers, which decreases their effectiveness. Hospital-based real-time data integration systems are also expensive in maintaining without proper infrastructure making them challenging to integrate in resource poor settings (Koch et al., 2022).

5. Clinical Outcomes and Future Perspectives

Several academic studies corroborate that integration of clinical data obtained from the laboratory in real time does improve a patient's experience at a clinical level. For instance, cutbacks on hospital turned infections through real time guided antimicrobial photographs has been one of the great achievements in Turkish tertiary hospitals (Chalasani et al.).

Likewise, the broader applicability of such systems which has been beyond dosage adjustments was proven by the improved level of control of infection in such diabetic patients who utilized the real time monitoring of na glucose (Simonov et al., 2019).

The future research will probably shift more to the phramacogenetic applications schemes including incorporation of these data into dosing algorithms. Studies like those of Simonov, et al. (2019) strongly suggest that inclusion of real-time laboratory data in the dose setting process in patients with specific genome characteristics will improve further medicine precision.

Methodology

1. Study Design

This was a tertiary hospital in which a retrospective observational study took place in order to determine the qualitative effects of federating real-time laboratory data on the practice of precise

dosing in the population of high-risk patients. The study sought to review clinical outcomes, operational efficiency and safety of medications.

2. Study Setting and Population

The research was conducted in the IPD wards alongside the ICU's of a tertiary hospital. The population of patients recruited to the study included adults who were 18 years and older age and:

- Required a dose of medications that necessitate special compliance such as aminoglycoside, vancomycin, warfarin, or any chemotherapy agent.
- Kept a minimum of two critical laboratory parameters in focus during the hospitalization period which included renal function which were serum creatinine, liver enzymes which involved ALT/AST, or INR coagulation profiles.

3. Data Collection

The following types of information were extracted from the EHR and laboratory information systems of the hospital:

- Patient demographics: Age, sex, comorbidities.
- Medication data: Drug type, dosing regimen, and changes during therapy.
- Laboratory data: Real-time measurements of renal, hepatic, and hematological parameters.
- Clinical outcomes: Incidence of adverse drug reactions (ADRs), length of hospital stay, and mortality.
- Operational metrics: Time to dose adjustment after laboratory result availability.

4. Intervention

A real time data integration patient-centered platform has been developed that links the LIS with the EHR. Automated alerts were sent out to the clinical pharmacy team and clinicians when critical laboratory parameters were met and required immediate dosing change. The system was functional throughout the study period and all changes in the dosage were recorded.

5. Outcome Measures

The study focused on the following outcomes:

- Primary Outcome: Precision of dosing change dependent upon real-time laboratory results as per measured by effective target provision completion(e.g., target INR for warfarin, therapeutic range for vancomycin levels).
- Secondary Outcomes:
  - Reduction in adverse drug events (e.g., nephrotoxicity, bleeding).
  - Time from critical lab value availability to dose adjustment.
  - Changes in patient outcomes, including length of stay and mortality.

6. Statistical Analysis

Using statistical software, the data was evaluated. Means and standard deviations were utilized to portray continuous variables, while frequencies and percentages served for categorical variables. The comparative analyses comprised of:

- Paired t-tests to evaluate pre- and post-intervention differences in outcomes.
- Chi-square tests to compare categorical variables, such as the incidence of ADRs.
- Regression analysis to assess predictors of successful dose adjustments and their association with clinical outcomes.

7. Ethical Considerations

The research followed all the provisions of the Declaration of Helsinki. This study was approved by the ethical board of the hospital. The study was retrospective in nature with minimal risks since it

involved secondary data, and hence informed consent was waived. The patient's identity was protected through anonymization in the database.

8. Implementation Challenges
Challenges encountered during the study included:
- Inconsistent documentation of dose adjustments in the EHR.
- Occasional delays in laboratory result entry due to technical issues.
- Variability in clinician responsiveness to automated alerts, leading to missed adjustments.

9. Quality Assurance
To ensure data accuracy and reliability:
- Data extraction was cross-verified by two independent reviewers.
- A pilot study was conducted on a subset of patients to refine data collection procedures and validate the functionality of the integration platform.

10. Limitations
- The study's retrospective nature limits the ability to infer causality.
- Findings may not be generalizable to non-tertiary hospitals or healthcare systems with different infrastructure.

Findings
1. Study Population
In the current study, a total of 500 patients were evaluated for various procedures. From the sample evaluated, 300 (60%) females were evaluated, from which the age of this group was 55.4 ± 12.6 years. Most of the females, chronic kidney disease (35%) also reported suffering from sepsis (25%) and having cardiovascular factors (20%).

Characteristic	Value
Total Patients	500
Male Patients	300 (60%)
Female Patients	200 (40%)
Mean Age (± SD)	55.4 ± 12.6 years
Common Comorbidities	CKD (35%), Sepsis (25%), Cardiovascular (20%)

2. Primary Outcome: Therapeutic Target Achievement
The integration of laboratory data systems enhanced the achievement of therapeutic targets. For instance, the proportion of patients that achieved therapeutic levels with vancomycin grew from 55% to 85%, and the therapeutic targets for INR with warfarin grew from 60% to 88%.

Medication	Pre-Implementation (% Achieved Target)	Post-Implementation (% Achieved Target)	p-value
Vancomycin	55%	85%	<0.001
Warfarin	60%	88%	<0.001

3. Secondary Outcomes
(a) Reduction in Adverse Drug Events
There was a marked decrease adverse drug reactions (ADRs) which were recorded. The rate of nephrotoxicity associated with aminoglycosides and vancomycin use was reduced from 25 percent to

10 percent, while the rate of bleeding occurrences in patients treated with warfarin decreased from 20 percent to 8 percent.

ADR Type	Pre-Implementation Incidence (%)	Post-Implementation Incidence (%)	p-value
Nephrotoxicity	25%	10%	<0.001
Bleeding Events	20%	8%	<0.001

(b) Time to Dose Adjustment

The mean interval between the provision of the crucial lab result and the change in dose amounts was efficiently optimized as well, going from 4.8 ± 2.1 hours to 1.2 ± 0.8 hours.

Metric	Pre-Implementation	Post-Implementation	p-value
Time to Dose Adjustment (hrs)	4.8 ± 2.1	1.2 ± 0.8	<0.001

(c) Patient Outcomes

The average length of hospital manner reduced to about 2 days after the implementation alongside a decrease of the mortality rate to about 8% from 12%.

Outcome	Pre-Implementation	Post-Implementation	p-value
Length of Stay (days)	12.5 ± 4.2	10.3 ± 3.6	<0.001
Mortality Rate (%)	12%	8%	0.02

4. Operational Efficiency

The alert automation received an enhancement whereby the clinicians who responded to it rose from 65% to 90%. Additionally the amount of dose adjusting that was ignored was reduced by 75%.

Metric	Pre-Implementation	Post-Implementation	Improvement (%)
Clinician Alert Responsiveness	65%	90%	+25%
Missed Dose Adjustments	40	10	-75%

Summary of Findings

- Improved therapeutic target achievement: Significant increases in target-level attainment for critical medications.
- Reduced adverse drug events: Substantial decreases in nephrotoxicity and bleeding events.
- Operational gains: Faster response times and fewer missed adjustments.
- Better patient outcomes: Reduced length of hospital stay and lower mortality rates.

Discussion

The results of our research highlight the importance of incorporating real-time laboratory information alongside precision dosing activities within a tertiary hospital. We observed remarkable outcomes in terms of the amount of therapeutic target achieved, the number of adverse drug reactions reported, the operational efficiency, as well as the overall fimdings pertaining to the patients.

1. Therapeutic Target Achievement

There was a significant increase in the achievement of therapeutic target, such as: both warfarin and vancomycin from 55% to 85% and 60% to 88% respectively which could be achieved with the capture of adequate laboratory data on time. This finding in fact corroborates with prior studies such as that of Koch et al. (2022) that reported that timely monitoring and supervision of a therapeutic drug in real-time enables an accurate drug dosing for patients in critical condition. It is likely that the

introduction of automated alerts and faster access to the laboratory results played a role in the improvements so that dosing decisions could be made.

2. Reduction in Adverse Drug Reactions

The literature corroborates the findings of the observed reduction in adverse drug reactions, specifically nephrotoxicity as well as bleeding events. For instance, Simonov et al. (2019) achieved similar results in their study when combining aid in high risk drug monitoring with real time laboratory tests. The provision of real time laboratory data prevents drug toxicity and underdosing by allowing intervention at appropriate times using critical thresholds. Such outcomes are particularly important in sensitive groups, such as those patients suffering from chronic kidney disease, where the timely intervention could be required to prevent the impact being detrimental.

3. Operational Efficiency

The considerable decrease in the time between when a critical lab value is available and the time when a new dose is adjusted from 4.8 hours to 1.2 hours indicates the true evolution of the system's effect on the workflow. The increase in clinician alert to 90% from 65% further complements the effectiveness of the integration. Such results have been reported by Waitman et al (2011): use of real time alerting systems improved physicians responsiveness to alerts and reduced the delays experienced in critical decision making processes. The problem of alert fatigue remains one of the possible obstructions towards the achievement of long-term sustainability and requires more research.

4. Improved Patient Outcomes

The two-day decrease in the duration of hospital stay and a decrease in death rate from 12% to 8% denote improvement in the patient care. These results are in accord with the studies by Koyner et al. (2018), Chalasani et al. (2023), which relate the use of real time data to improved clinical outcomes for high risk patients. Less time in hospital is an advantage for the patients and also lowers the costs to healthcare systems, hence proving the point of making investments into health informatics tools.

5. Challenges and Limitations

Despite these successes, several challenges were noted:

- Data Integration and Interoperability: Although the integration platform worked, persistent data entry issues and communication gaps between the laboratory and electronic health systems, stress the importance of having a more sophisticated infrastructure.
- Alert Fatigue: Improvements in clinician responsiveness cannot be seen to mask the potential dangers that come with alert fatigue which may decrease the effective use of the systems in times to come. Solving this issue may involve adjusting the alert thresholds and emphasizing important notifications only.
- Generalisability: The outcomes might not be completely applicable to other medical facilities with distinct resources or demographics since this is a single institution research carried out in a tertiary center.

6. Future Directions

The study highlights several areas for future research and development:

- Expansion to Pharmacogenomics: Integrating pharmacogenomic data with real-time laboratory results could further enhance precision dosing, particularly for drugs with narrow therapeutic indices.
- Artificial Intelligence Integration: AI-driven models could refine dosing recommendations by incorporating additional patient-specific variables, such as comorbidities and genetic profiles.
- Cost-Benefit Analysis: Further studies are needed to evaluate the economic impact of real-time data integration, particularly in resource-limited settings.

7. Clinical Implications

Findings of this research indicate that real-time laboratory data integration should be empowered at tertiary hospitals and also stand to be beneficial for other hospitals by enhancing therapeutic precision which in turn would lower adverse effects and , as a result, improve patient outcomes, which in effect will smoothly raise the level of care provided to high-risk patients. In order to unlock the potential of these technologies, hospitals must focus on enhancing their health informatics infrastructure along with training clinicians.

Conclusion

This study investigates the novel enhancement on precise drug dosing as a result of connectivity to real-time in laboratory data at a tertiary hospital. Because timely using data enabled decisions, the system improved clinical and operational outcomes which further demonstrates its worth as an integral aspect of healthcare services.

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