Review Article

Utilizing Data Analytics And Business Intelligence Tools In Laboratory Workflow

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Abstract

A business intelligence (BI) tool in a laboratory workflow offers various benefits, including data consolidation, real-time monitoring, process optimization, cost analysis, performance benchmarking (quality indicators), predictive analytics, compliance reporting, and decision support. These tools improve operational efficiency, quality control, inventory management, cost analysis, and clinical decision-making. This write up reveals the workflow process and implementation of BI in a private hospital laboratory. By identifying challenges and overcoming them, laboratories can utilize the power of BI and analytics solutions to accelerate healthcare performance, lower costs, and improve care quality. We used navify (Viewics) as a BI platform which relies on an infinity data warehouse for analytics and dashboards. We applied it for pre-analytic, analytic and post-analytic phases in laboratory. We conclude, digitalization is crucial for innovation and competitiveness, enhancing productivity, efficiency, and flexibility in future laboratories.

Introduction

It has been accepted that digitalization is a powerful engine for economic growth in today world [1]. Data analytics are becoming an increasingly important part of daily operations and quality improvement efforts within clinical laboratories. Business intelligence (BI) dashboards are one of the key components of data analytics since they provide decision makers timely access to summarized analyses and visualizations [2]. Dashboards typically display the status of key performance indicators (KPIs) and other metrics or summary statistics on a single screen, providing information for specific objectives at a glance. These BI dashboards can enhance healthcare organizations' financial and operational performance and quality of patient care. These BI tools allow us to remove manual steps done using Excel worksheets, for example data handling, using excel formulas and generating visual graphical works. Today what leadership roles needs are to: (a) determine clinical need and strategic direction for local environments, (b) ensure technology solutions are cost-effective, safe and reliable, (c) assume the business acumen to market, negotiate and manage change in services, (d) expect understanding of the clinical bioinformatics that underpin genomics, health information science (data mining and health economics) and physical sciences (e) expect

knowledge and skills in the provision of direct clinical care in the face of staffing shortfalls experienced by many healthcare systems and (f) enhance their communication and interactive skills. In growing their leadership contribution, a partnership approach in education and training across healthcare divides, in conjunction with the diagnostics and/or information technology industries, through integrated professional organization approaches, joint approaches with academia and policy related healthcare organizations are recommended [3,4]. Either we can built our own dashboard using open-source programming languages like R or Python programming language or can use available laboratory tailored BI tools from vendors [5,6]. There are multiple options available in market to use variety of user-friendly BI tools such as Microsoft Excel and Power BI, GraphPad, Tableau, and tools specific to one's EHR such as SlicerDicer that could be utilized for a variety of data analyses, reporting, and visualization purposes. But to have specific lab related BI tools which increases the collaboration with information technology, applications development, and business intelligence teams would be a valuable resource to help meet the data analytics needs of one's clinical laboratory. We have introduced the modern-day digitalization tool in our work area to monitor laboratory effectiveness and efficiency. This digital tool named navify (Viewics) works on Roche Platform covering the major bulk test menu in the laboratory, is a data analytics platform that offers dashboards and insights using Tableau. This is a web-based tool connected with hospital laboratory information system (LIS) via middleware Infinity provided by Roche, which is a lab IT solution that aids in managing workflow and data [7]. This paper delves into the multifaceted challenges faced by private laboratories in the Middle East when implementing BI and analytics solutions within their workflows. Through an in-depth literature review along with our personal experience, this study aims to shed light on the intricate interplay between the unique characteristics of laboratory operations and the complexities of implementing data-driven technologies. By identifying these challenges, laboratory professionals, IT stakeholders, and decision-makers can gain a comprehensive understanding of the potential bottlenecks and obstacles that might impede successful adoption. The subsequent sections of this paper will scrutinize key steps, encompassing issues related to data quality, integration with existing systems, privacy and security concerns, organizational change management, and the scarcity of domain-specific expertise [3,8]. By dissecting these challenges, this study seeks to provide insights that can guide laboratories in the Middle East toward informed decision-making and effective implementation of BI and analytics solutions.

How we started our journey

We, The International Medical Center (IMC) is a 300-bed tertiary care hospital located in Jeddah, Kingdom of Saudi Arabia. Built in 2005, IMC covers more than 30 specialties. Highly qualified staff, paired with the state-of-the-art facilities, support IMC's strategic pillars-wellness, quality, patient experience, digitization, people, medical and finance. To maintain its ranking among the region's best healthcare providers and to align with global healthcare practices, IMC has focused on creating a digitalization purpose-driven culture. This digitization empowers IMC to provide excellent care, improve patient experience, and optimize operations. Together, these factors provide a holistic approach to healing patients. Digitization requires adopting a digital mindset that recognizes the ongoing and fluctuating nature of the journey. IMC first created a 3-year digital transformation roadmap in 2019 that included 55 initiatives. The roadmap allows for additional initiatives to meet market trends, business requirements and ongoing institutional needs. In November 2020, we have implemented the use of navify (Viewics) to monitor our laboratory KPIs. Specific utilities of a BI tool in our laboratory workflow includes data consolidation using Infinity (Roche middleware). This middleware solution describe a software that functioned as a mediator between laboratory analyzers and the laboratory information system (LIS) [9]. This allows for a comprehensive view of laboratory operations and facilitates data-driven decision-making. By analyzing historical data and trends, BI tools can identify inefficiencies and difficulties in laboratory workflows. This insight enables process optimization, resulting in reduced turnaround times, improved productivity, and better resource allocation [10]. Here we choose data intensive dashboard (navify analytics for core lab) for monitoring Pre-analytic Volume, Analytic Turnaround Time, Post-Analytic Workload Analysis and Instrument Utilization. A dashboard represents a customized graphical view of some subset of the underlying preferred dataset(s). Vendor-specific middleware and commercial analytics platforms build dashboards and share them with business users; either individually, website or as part of an application. If a business user is given permissions to the report, they can build their own dashboards too. Laboratory dashboard (Figure 1) provides you with the overview needed as a laboratory director or as a facility manager. Gathering in one central point all the data on every division of the laboratory phases will be of great help to run it smoothly, giving you big picture of the facility. These serves as quality indicators (QIs). Indeed, QIs are improving tools for measuring the quality of selected aspects of care by comparing them against defined criteria [11,12]. This promotes accountability, help in decision makings to set priorities and thus help in comparison to be made between timelines and setting effective interventions.

Pre-Analytic Monitoring

Major bulk of laboratory errors occur at pre-analytic stage of almost 70% or more [13,14]. Organizations use different options for pre-analytic solutions to overcome this greatest challenge to laboratory professionals. We are using Roche solutions and observing the workload on navify such as Order Volume, Sample Volume and Count of tests by test (Figure 2). Usually pre-analytic phase has always been an area of focused for improvement in sample collection such as sample rejection due hemolysis, lipemia, wrong barcode label, specimen lost, etc [15]. Other than

that most striking QI would be workload analysis of phlebotomy done. Good laboratory practice includes balance requirements of staff to adequately provide patient services [16]. Laboratory testing generally begins with phlebotomy tasks. One of the obvious challenge that laboratory face and should handle in effective manner is deploying phlebotomy services considering the peaks and valley of patient influx. By having volume data of pre-analytic we have been able in removing excess staff and thus improving cost reduction. Other than that we have been able to correct appropriate work force required on specific day time and area has been corrected and the service outcomes improved. The patient's prediction for improved staffing is one of the striking feature for the one who likes to use pre-analytic QI dashboard [17]. This helps us implementing the concept of Lean and Six Sigma process improvement at pre-analytic phase of laboratory. We implemented methodical modifications to inpatient and outpatient phlebotomy services achieving higher patient satisfaction. This resulted due to improvement in the timeliness of specimen collections and shortening waiting time for patients. By this we have been able to improve motivation for work and decrease the absenteeism rate among the staff. Other than that by monitoring 'Change in Sample Volume and Number of Individual Tests' (Figure 2) is a useful tool. Although laboratory services only account for 5 percent of a hospital's budget, they influence 60 to 70% of all important decisions, including patient admittance and discharge [18]. This BI data determining the true potential cost savings or new net revenue from projects under consideration by the hospital system. The other utility of pre-analytic monitoring, we are exploring is blood concentrations of various analytes change during the course of the day. These cyclical variations can be significant, so the timing of sample collection should be strictly controlled. Chemistry analytes such as hormones levels are affected by circadian variation [19]. With the help of navify we are able to monitor timing of sample collection of such tests, e.g. TSH, cortisol, testosterone, etc. With such informative data, we are able to guide our physicians and patients.

Analytic Monitoring:

BI tools are often a good choice for a laboratory to start when approaching an analytic problem, as it is easier to understand visualized data. By using navify we have been able to monitor our laboratory turnaround time (TAT), a promising quality indicator for analytic business tools. TAT is one of the most important measurable tools of laboratory service and is always been used as a key performance indicator of laboratory performance. By monitoring TAT one can organize workflow in the laboratory [20]. According to the International Organization for Standardization (ISO) guidelines, each laboratory shall establish turnaround times for each of its tests that reflect clinical needs in consultation of physicians, and shall periodically evaluate whether or not it is meeting the established turnaround times. TAT prolongation can be minimized by checking the outliers and reason behind them. Increase TAT would cause delay in diagnosis and treatment of patients. Holland et al. claim that there was 43% treatment delay and 61% increased length of stay in the emergency department due to raised TAT [21]. Other effects of delay TAT might be increase in workload due to reorder of tests by physicians as STAT, thus increasing the cost burden of health care. Therefore strict monitoring of TAT is required for effective laboratory management in addition to focused business QI. We have been able to monitor TAT using navify (Figure 3). Total laboratory automation improves the efficiency of the laboratory. Reporting improvement in laboratory productivity leading to decreased laboratory workforce has been recently claimed by Al Naam et al [22]. As less workforce is required to operate TLA, this reduce labor work is transferred to handle problems in rectifying outliers in pre and post-analytic area, so consequently improving total TAT. This has also been achieved using this BI in our laboratory work. In addition to just simple monitoring of TAT, we have been able to use monitoring, change in TAT and outliers for different tests such as cardiac markers, renal functions tests, liver function tests, hormones, etc. This gives us an edge on having additional information to improve our business strategies as we monitored change and reason behind of improvement or decline in our system. To cope up with high volume complexed tests, clinical laboratories in advance era equipped with high throughput auto-analyzers and even total laboratory automation. By using highly sophisticated automated analyzers, massive amount of laboratory data are generated. Mostly the auto-validation rules are set in to cope up with high demand results within TAT [23]. Auto-validation rules are designed based on auto-release range using clinical decision points, analytical measurement ranges, delta checks and dilution rules. The use of interactive dashboard for auto-validation allows visual display and enables the data-driven decision-making process ease for us. Monthly more than 95% results are auto-validated based on our laboratory set rules (Figure 3). This improves our business goal by providing timely results to ordering physicians. We found auto-validation as another machine learning tools which improves our experience of analytic throughput by auto-validation and increase reliability that have been traditionally subjective when performed by humans.

Post-Analytic Monitoring

Post-analytics phase is the end stage of testing process, in which not only test results are finalized with reference ranges but also other important aspect of laboratory management are dealt with [24]. What important aspects other than TAT we focused are instrument utilization, improved supply chain, workload monitoring by instruments, by weekdays and by hours and supply chain. All the data from instrument log files and infinity (middleware) is used to gather these important information.

The scope of service of a modern day laboratory is most likely dependent upon availability of highly sophisticated and complexed laboratory instrument. To achieve our business goal, one should know about instrument utilization. This data about work quantification have substantial impact on how laboratories

should manage business. The insufficient visibility into instrument availability and utilization is a challenge for many laboratory that is faced nowadays due to lack of data utilization. We have been able to overcome this problem by using navify. We have different analyzers placed at different locations connected to navify digital solutions and are monitoring the utilization by workload balance ratio (Figure 4). This process mining enables us to review preventive maintenance policies and processes during machine downtime as suggested by Tsai et al. [25]. By using the factual BI software, laboratory can collect and analyze real-time data about the performance of their laboratory in areas such as operations and finances, as well as personnel management. It is obvious to use laboratory instrument and staff efficiently to keep our business goals alive and prosperous. For this simulation tool in healthcare is applied by different researchers [26]. Lote et al. focused to increase resource utilization by having laboratory personnel use resources more evenly [27]. Bottlenecks in the existing and potential configurations of laboratory tests were assessed by Kadi et al. [28]. In order to determine which resources had the highest utilization, the writers calculated each resource's utilization. We have been able to deploy staff according to much needed area as navify give us true insights to define staffing schedules to cover demand from pre to post analytic phases (Figure 4). Getting this level of insight in such an intuitive way allows us to redirect resources where they are most needed and optimize areas that are not performing well to ensure the best return on investment possible. We found sample workload that is sample throughput is measurable business intelligence tool [29]. The maximum throughput of each resource must be known in order to calculate the maximum throughput of a laboratory; however, it might not be able to gauge staff work pace when faced with their maximum workload. The goal is to maximize throughput in general. A higher throughput corresponds to a higher production rate, implying that more samples were processed in the laboratory throughout a given time period. Laboratories with a suitably high maximum throughput can handle peak demand and, in the event of machine breakdown, can quickly process delayed samples when the laboratory is operating again or using backup laboratory analyzers. More obvious advantage for this BI tool is that laboratories may elect to accept more samples, such as those from other laboratories and even clinical trials. Any clinical laboratory can increase its capacity to do more with less and do it effectively, giving more value for the money spent on healthcare, by rethinking workflow and procedures. Things to focus on data for workload completion. Once we have data, we can easily correct causes of outliers. This definitely boost productivity, efficiency and quality in a clinical lab. And this feature has been the consistently used by our laboratory management.

What Additional Features can benefit - Recommendations

Although we have successfully implemented the policy of 'Reporting of Critical Values' in our hospital but our wish list for improving dashboard for BI includes addition of data for critical laboratory result. Informing of critical laboratory value in timely manner always affect patient treatment and hospital stay [24,30]. All laboratories must follow strict guidelines for reporting critical values, as mandated by the international and local accreditation agencies such as College of American Pathologists (CAP) [31]. This includes implementing a strong quality assurance system. Laboratory critical value is always has been listed and agreed depending upon a number of variables, including variations in staffing, equipment, patient demographic and clinical demand in a hospital. Laboratory professionals working together with other stakeholders in the delivery of healthcare has been able to develop hospital wide critical laboratory values. Laboratory supply chain management is so crucial for critical ill patient that if not managed correctly will lead to disaster for hospital management. Focusing on unforeseen problems in maintaining and delivering laboratory supplies can be easily handled by using valuable analytics. Having the analytics available both descriptive and predictive models can be applied enhancing the decisions for negotiating prices, reducing the variation in supplies, and optimizing the ordering process as a whole. This will keep the supply chain well-organized from end to end and avoids bottlenecks. McHugh has claimed reduce in waste and reduce inventor expenses by almost 8 percent which gives more focused understanding of operations [32]. Using the artificial intelligence or predictive analytics features such as forecasts or value comparisons can give data alerts using the database available. By creating this future prediction dashboard will explore available data and predict business future. By this feature one will be able to view data from the past, present, and future on a single screen.

How BI will impact laboratories in future, concluding remarks

In summary, a business intelligence tool (BI) in laboratory workflow offers numerous utilities that improve our operational efficiency, quality control, inventory management, cost analysis, decision support, and compliance reporting. It empowers laboratory managers and personnel with valuable insights to enhance performance, optimize processes, and deliver better patient care. This monitoring bring insights about the interrelationships among BI value to our diagnostic laboratory. It has been shown by Phillips-Wren G and McKniff S et al. that "how the choice of visualization of workflow and operational processes impacts decisions to embrace real-time, big data technology" [33]. The findings help IMC Lab to focus on what causes the benefits related to BI implementation that lead to greater competitive advantage. As laboratories grapple with the imperative to advance their workflows through data-driven strategies, a nuanced comprehension of the challenges they encounter is pivotal. By navigating these hurdles, laboratories can harness the transformative potential of BI and analytics solutions to expedite their progression towards efficiency, innovation, and excellence. This Digital transformation is an opportunity to accelerate healthcare performance by lowering cost and

improving quality of care [4,34]. We found navify as one of the ideal laboratory BI platform to achieve our business targets. This and other BI tools in markets as procedure of digitalization is to be seen as required to pursue innovation and remain competitive. In laboratories of the future, laboratory workflows will be more productive, efficient, and flexible due to these BI tools. True laboratory BI is definitely understanding the required data in a way that it brings solution to our laboratory business.

Declarations

Funding

No funding was required or done.

Ethical approval

The study has been approved by Institutional Review Board, International Medical Center, Research Center, Jeddah, Kingdom of Saudi Arabia (IRB approval # 2023-09-226). However, because of the nature of the study (retrospective review of records), informed consent was not required from the study subjects. The need for informed consent was waived by an IRB.

Consent to Publish

Not applicable.

Availability of Data and Materials

Data is available on request.

List of Abbreviations

Business intelligence (BI);
College of American Pathologists (CAP);
International Medical Center (IMC);
International Organization for Standardization (ISO);
Key performance indicators (KPIs);
Laboratory information system (LIS);
Laboratory turnaround time (TAT)
Quality indicators (QIs)

Competing interests

The authors declare that they have no competing interests.

Authors' Contributions

IM: Protocol development, gaining ethical approval, manuscript writing.

FJD: Record review and data collection, data analysis, manuscript writing.

All authors reviewed and edited the manuscript and approved the final version of the manuscript to be published.

Figure 1: Analytic Dashboard For Core Lab

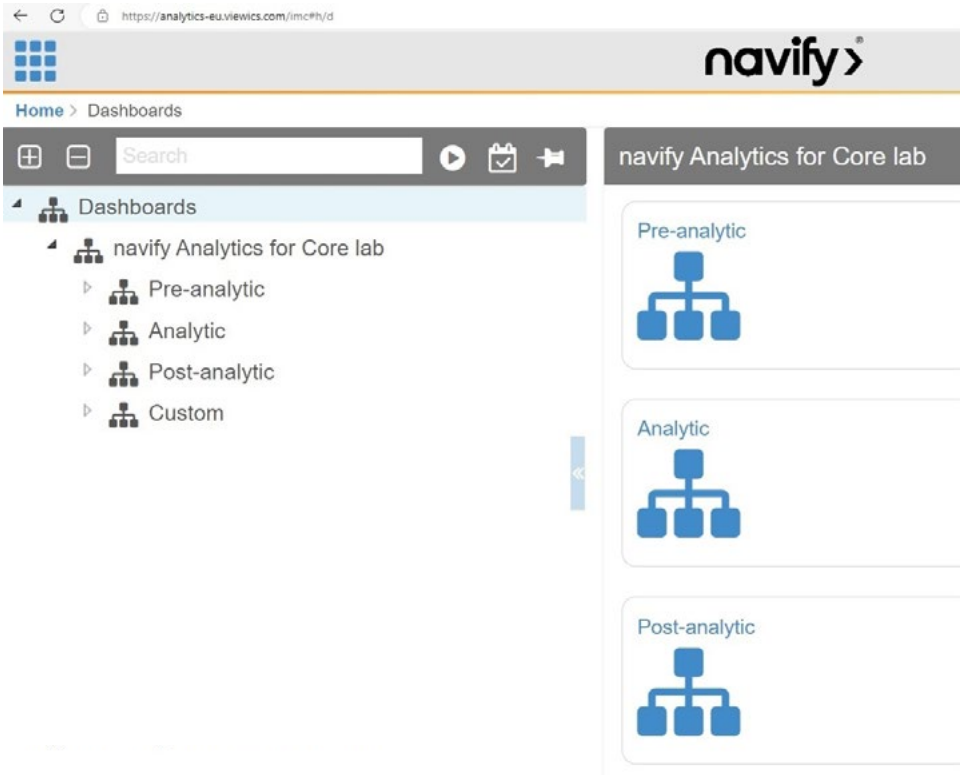
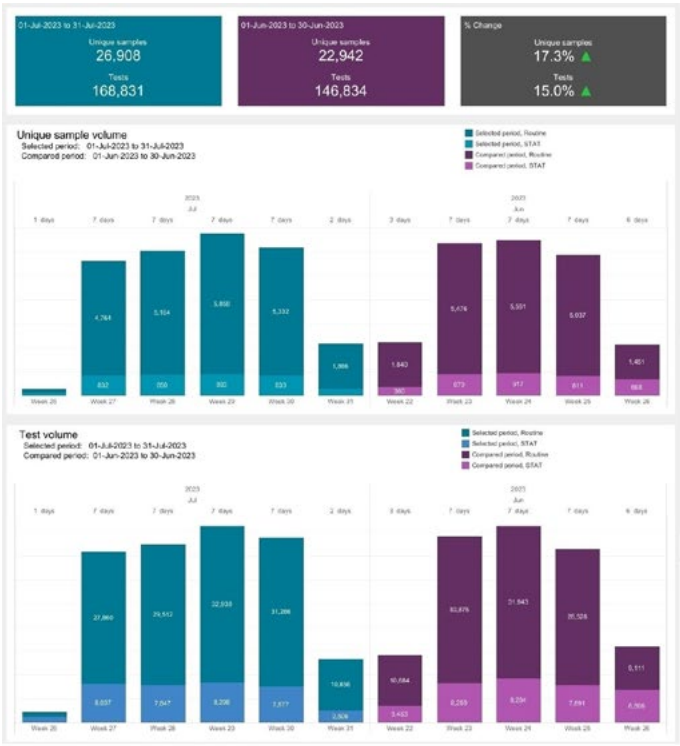
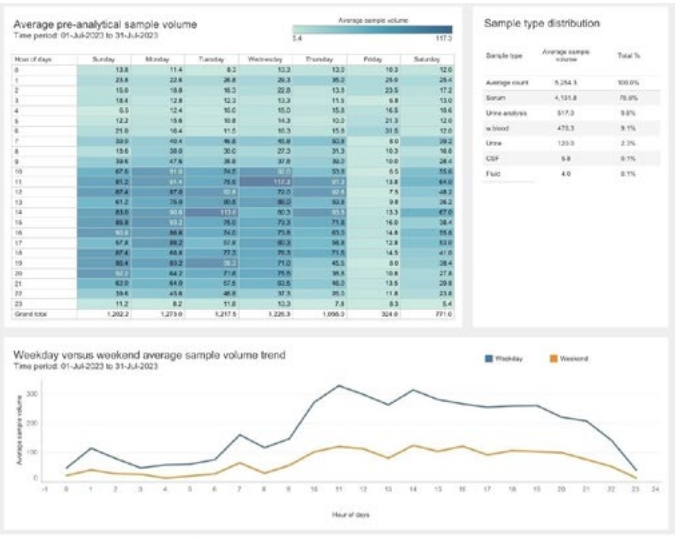


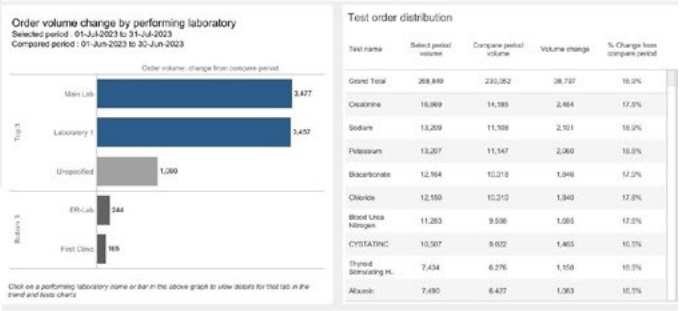
Figure 2: Pre-Analytic Monitoring - Change in Order, Sample And Test Volume
a) Pre-Analytic Sample & Test Volume Percent Change in Orders
b) Pre-Analytic Sample Volume By Hours Of Days
c) Order Volume Change By Laboratory Site



a) Pre-Analytic Sample & Test Volume Percent Change in Orders



b) Pre-Analytic Sample Volume By Hours Of Days



c) Order Volume Change By Laboratory Site

Figure 3: Analytic Monitoring - Turnaround Time and Auto-Validation
a) Monthly Turnaround Time Distribution
b) Yearly Turnaround Distribution
c) Auto-Validated Test Volume Per Sample
d) Analytic Volume Percent Change Turnaround Time For Cardiac Markers

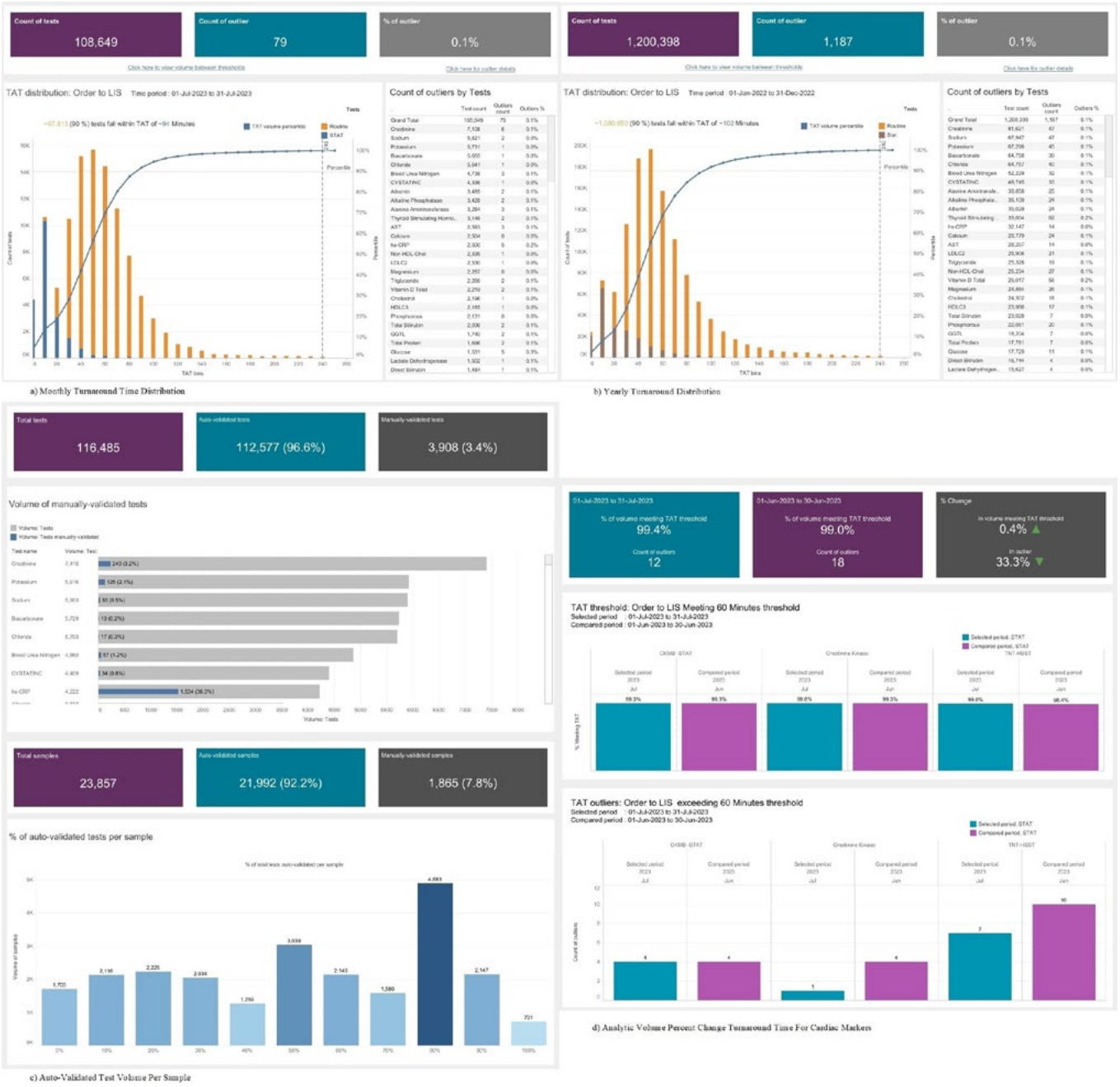


Figure 4: Post-Analytic Monitoring - Workload
a) Analytic Workload Balance Daily Ratio By Instruments
b) Instrument Utilization Percent For Each Instrument In Lab
c) Sample Workloads By Days And Hours On Different Lab Instruments
d) Monitoring Daily Workload Completion
e) Test Analyzed By Days And Hours
f) Test Analyzed On Different Analyzer With Number Of Sample Analyzed And Test Result
g) Test Rerun Overview

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