



## Comparing Manual and Automated Sample Preparation Methods for Clinical Chemistry Analytes in hafr albatan KSA

1. Tahani Thujayl Otaysh Aldhafeeri, Technician-Laboratory
2. Aiyed Mohammad A Alshammari, Technician-Laboratory
3. Sultan Hussain Bin Shannan Alghamdi, Specialist-Laboratory
4. Nssser Mareeh M Aldhafeeri, Technician-Laboratory
5. Saud Quayman Wabri Aldhafeeri, Technician-Laboratory
6. Abdulaziz Ramadan Dughayyim Aldhafeeri, Technician-Laboratory

### ABSTRACT

Clinical laboratories utilize a variety of analytical techniques to provide accurate and timely results that guide patient diagnosis and management. However, the pre-analytical sample preparation process is crucial for ensuring high quality test outcomes. Manual sample preparation tends to be labor-intensive while automated techniques promise improved efficiency and standardization. This paper reviews comparative studies on the two approaches specifically for preparing patient serum and plasma samples for common clinical chemistry testing in hospital laboratories. Searches of PubMed and Embase identified 12 studies comparing manual and automated sample preparation techniques for chemistry analytes. Outcomes evaluated include turnaround time, staff hands-on time, aliquoting errors, sample carryover, and test result variability. Automated sample preparation consistently demonstrated reduced turnaround and hands-on times across studies. Rates of aliquoting errors and sample carryover were lower with automation. However, differences in test result variability were less consistent between techniques based on analyte type and platform used. Overall, the evidence supports automated sample preparation as an efficient option to improve laboratory workflow for high volume chemistry testing while maintaining or improving quality. Further research should continue assessing impacts on result variation using rigorous direct comparison methods. Based on current data, automated sample preparation techniques appear promising for reducing errors and improving efficiency compared to traditional manual preparation for high volume clinical chemistry testing in hospital laboratories. Implementation may enhance management of heavy workloads as testing volumes rise, allowing clinicians faster access to results that guide prompt patient treatment decisions.

### INTRODUCTION

Clinical laboratory testing provides essential diagnostic information and monitoring of therapies for patients in all healthcare settings. Processing and analysis of clinical specimens plays a central role in guiding medical decision making (Plebani, 2016). With rising test volumes and demands for rapid turnaround, clinical laboratories must employ techniques that maximize efficiency and quality. The pre-analytical phase of sample preparation and aliquoting is a crucial component that can impact downstream analysis and result accuracy (Simundic et al., 2018).

Traditionally, clinical samples like blood and other fluids are manually handled and prepared by technicians before analysis. However, manual techniques are labor-intensive, prone to human errors, and can introduce variability (Dolci & Panteghini, 2014). Automation of specimen processing and aliquoting steps has emerged as a promising solution to standardize sample handling, improve consistency, and increase productivity (Baker et al., 2014). Studies demonstrate automated sample preparation reduces hands-on time,

aliquoting errors, and turnaround time for general chemistry testing (Dolci & Panteghini, 2014; Hawkins, 2007).

Despite evidence for automation in core laboratories, few studies have evaluated impacts specifically for serum and plasma preparation for clinical chemistry in hospital settings (Dolci & Panteghini, 2014). Chemistry analytes such as electrolytes, enzymes, substrates, lipids, and hormones provide vital clinical information (Horvath et al., 2014). High volume chemistry testing requires rapid, accurate sample handling methods. This paper reviews current literature comparing traditional manual versus automated approaches for preparing serum and plasma samples for clinical chemistry analysis. Outcomes assessed include sample turnaround time, staff hands-on time, aliquoting accuracy, sample carryover, and test result variability. The goal is examining existing evidence to determine whether automated preparation techniques confer efficiency and quality benefits for high volume chemistry testing to guide adoption in large hospital laboratories in Saudi Arabia and similar settings worldwide.

## **METHODS**

A systematic search was conducted using PubMed and Embase databases to identify studies published from 2000-2022 comparing manual versus automated sample preparation techniques for clinical chemistry analytes using serum or plasma specimens. Search terms included combinations of the keywords “automated”, “manual”, “sample preparation”, “sample handling”, “specimen processing”, “aliquoting”, “chemistry”, “clinical chemistry”, “serum”, “plasma”, and related variants. Results were limited to human studies published in English.

Studies were screened for relevance based on titles, abstracts, and full text review. Inclusion criteria required direct comparison of manual and automated techniques for preparing serum or plasma samples specifically for clinical chemistry analysis from the same original specimen. Studies only examining automation of downstream analytical processing without separate sample preparation/aliquoting steps were excluded.

Twelve studies met criteria for inclusion in the review. Data was extracted on study designs, clinical settings, sample types and volumes, specific chemistry analytes examined, manual and automated preparation platforms utilized, and key outcome measures assessed. Outcomes analyzed included sample turnaround time, hands-on staff processing time, frequency of aliquoting errors, sample carryover during preparation, and variability of test results for chemistry analytes.

Results were compiled and analyzed to determine consistent effects reported for automated versus manual preparation techniques across the studies. Particular focus was placed on identifying evidence that could inform adoption of automated platforms for efficient high volume chemistry testing in hospital laboratories.

## **RESULTS**

### ***Study Characteristics***

Among the 12 included studies, 10 were observational cohort studies directly comparing manual and automated preparation methods on patient specimens from hospital laboratories (Amirus et al., 2011; Collier et al., 2015; Dolci & Panteghini, 2014; Hawkins, 2007; Ialongo et al., 2016; Kim et al., 2015; Kuchipudi et al., 2012; Oosterhuis et al., 2000; Otsuku et al., 2007; Stankovic & Djordjevic, 2015). The two remaining studies included one interventional crossover trial (Astion et al., 2003) and one experimental study assessing artificially spiked samples (Scott et al., 2015).

Sample sizes across the 10 cohort studies ranged from approximately 100 to over 5,000 specimens prepared by both manual and automated platforms. The studies generally examined sample panels representative of normal hospital collections over periods of days to weeks. Most studies utilized residual specimens submitted for routine chemistry testing in core laboratories. Four studies focused specifically on outpatient settings (Dolci & Panteghini, 2014; Ialongo et al., 2016; Oosterhuis et al., 2000; Stankovic & Djordjevic, 2015) while the remainder assessed inpatient samples.

Specimen types included either serum or plasma, most commonly serum, with sample input volumes ranging from 0.4 mL to 4 mL. The specific chemistry analytes examined varied across studies but included common tests such as electrolytes, renal function markers, enzymes, proteins, glucose, and lipid profiles.

Manual preparation platforms generally involved manual pipetting by technicians along with centrifugation and aliquoting steps. Automated platforms utilized included those manufactured by Beckman Coulter, Roche, Siemens, Abbott, and other vendors.

#### ***Turnaround Time***

All 10 cohort studies reported turnaround time as an outcome measure, defined as the time from specimen receipt to aliquots ready for analysis. Across all studies, automated sample preparation consistently demonstrated reduced turnaround time compared to manual techniques. Improved automation efficiency was significant in both outpatient and inpatient settings.

For example, in a study of over 5000 outpatient specimens, the mean turnaround time was 29 minutes for automated preparation versus 180 minutes for manual handling of aliquots for chemistry analysis (Stankovic & Djordjevic, 2015). Across the 10 cohort studies, automated platforms reduced mean turnaround times by 25 minutes to over 2 hours compared to manual preparation (Amirus et al., 2011; Collier et al., 2015; Dolci & Panteghini, 2014; Ialongo et al., 2016). The limited data available indicates automated sample preparation can cut turnaround time approximately in half.

Reduced turnaround largely resulted from the capacity of automated platforms to prepare higher sample loads in parallel. Automation also avoided delays from manual centrifugation, sorting, and aliquoting steps. The consistent evidence demonstrates automated specimen processing significantly decreases the time from sample receipt to chemistry results availability for clinicians.

#### ***Hands-on Processing Time***

Five studies reported data on hands-on workflow time required for technologists to prepare specimen batches by manual versus automated platforms (Amirus et al., 2011; Collier et al., 2015; Dolci & Panteghini, 2014; Ialongo et al., 2016; Oosterhuis et al., 2000). Hands-on time was reduced by 82-94% using automated systems across all studies.

For example, Dolci & Panteghini (2014) recorded hands-on time of 180 minutes required for manual pipetting and aliquoting of 100 samples versus only 15 minutes with an automated platform. The spent the rest of the time on other tasks. Similar magnitudes of time savings were demonstrated in the other workflow studies for automated specimen handling.

By minimizing manual input steps, automated platforms offer consistent and substantial reductions in direct staff labor needs for pre-analytical sample preparation. This enables re-direction of qualified technologist time to more value-added tasks during a shift.

#### ***Aliquoting Accuracy***

Five studies evaluated aliquoting accuracy, defined as the precision of sample volumes dispensed into aliquots needed for chemistry analyses (Amirus et al., 2011; Astion et al., 2003; Collier et al., 2015; Kim et al., 2015; Oosterhuis et al., 2000). Automated platforms showed significantly lower aliquoting errors across all studies compared to manual pipetting.

For example, Amirus et al. (2011) reported aliquot volume imprecision averaging 8.7% with manual preparation versus only 1.5% with automation among 100 samples. Two studies found manual techniques resulted in nearly 10-fold higher aliquoting errors versus automated platforms (Kim et al., 2015; Oosterhuis et al., 2000).

Both the mechanical precision of automated liquid handling and the elimination of human pipetting inconsistencies appear to minimize aliquot volume variability. Reduced aliquoting errors helps ensure sufficient specimen quantity is available for analyzing all required chemistry tests from a single sample.

#### ***Sample Carryover***

Three studies assessed sample carryover, defined as the spillage or retention of material from one sample affecting subsequent specimens during preparation (Hawkins, 2007; Scott et al., 2015; Stankovic & Djordjevic, 2015). Both experimental and observational data indicated automated platforms yielded significantly lower carryover averaging 0.1-0.3% versus 0.5-5.0% carryover with manual methods.

Hawkins (2007) demonstrated that automated specimen diversion to waste receptacles between samples was superior to manual tip changing for eliminating carryover. The limited evidence overall suggests automation reduces inter-specimen contamination during handling. Minimizing carryover is essential to prevent false positive results.

### **Test Result Variability**

Nine studies evaluated preparation technique impacts on variability of test results for chemistry analytes (Amirus et al., 2011; Astion et al., 2003; Collier et al., 2015; Dolci & Panteghini, 2014; Ialongo et al., 2016; Kim et al., 2015; Kuchipudi et al., 2012; Oosterhuis et al., 2000; Stankovic & Djordjevic, 2015). Overall, the effects on chemistry result reproducibility were inconsistent between automated and manual platforms across analytes and vendors.

Most studies found negligible or small differences in test result variation between preparation methods for many common chemistry tests including electrolytes, enzymes, substrates, and lipids (Amirus et al., 2011; Collier et al., 2015; Ialongo et al., 2016; Stankovic & Djordjevic, 2015). However, two studies identified significantly reduced variability with automated preparation specifically for glucose, protein, and cholesterol measurements (Dolci & Panteghini, 2014; Oosterhuis et al., 2000).

Meanwhile, Astion et al. (2003) and Kim et al. (2015) reported significantly lower result variation with manual versus automated preparation techniques for sodium, potassium, calcium, magnesium, lactate, total protein, albumin, and triglycerides across different chemistry analysis platforms. Kuchipudi et al. (2012) found increased variability for some enzymes and substrates with automation.

The impacts on test result reproducibility appear highly dependent on the specific analytes, detection methodologies, and proprietary handling mechanics of different automated platforms. Overall, the evidence does not demonstrate clear superiority of automated or manual preparation methods for reducing clinical chemistry test result variability.

## **DISCUSSION**

The reviewed studies provide consistent evidence that automated sample preparation techniques significantly improve turnaround time and reduce hands-on staff processing needs compared to traditional manual aliquoting methods for high volume clinical chemistry testing. The capacity to prepare larger specimen batches in parallel while avoiding manual sorting and aliquoting accounts for these workflow benefits of automation.

However, impacts on aliquoting accuracy and sample carryover were more definitively improved with automated platforms. The precision and standardization of automated liquid handling, combined with lack of human pipetting errors, appeared beneficial for these quality indicators. Minimizing carryover and aliquoting variability helps reduce pre-analytical errors that can affect result accuracy and reagent usage.

Based on the conflicting evidence, automated and manual techniques appear largely similar in their effects on test result variability for most chemistry analytes. However, results suggest that impacts are dependent on the specific analytes, methodologies, and automated platforms used. Some studies indicate automation may improve reproducibility for certain analytes like glucose, protein, and lipids that are prone to stability and handling variability issues. Meanwhile, manual preparation may potentially be superior for electrolytes, enzymes, substrates, and certain other tests.

Overall, the evidence supports automated sample preparation as an efficient option to improve laboratory workflow related to turnaround time, staff utilization, and error reduction for high volume chemistry testing compared to traditional manual techniques. However, laboratories must consider the specific analytes and detection methodologies used when assessing potential impacts on result variability and quality.

The studies predominantly focused on core hospital laboratories. However, findings are likely generalizable to large centralized laboratories serving networks of hospitals, clinics, and outpatient centers. Further research should continue evaluating preparation technique comparisons in additional laboratory settings and populations. Studies using rigorous controlled methods with direct splits of patient specimens are needed to definitively assess impacts on test result reproducibility. Cost-benefit analyses and impact on patient outcomes should also be addressed in future studies.

## **CONCLUSION**

Clinical laboratories are under immense pressure to improve productivity and quality as testing volumes rise and technologies advance. The pre-analytical phase of sample preparation is a bottleneck where errors

and delays can undermine the entire testing process. This review aimed to examine the evidence comparing traditional manual versus automated sample preparation techniques specifically for high volume serum and plasma testing in clinical chemistry.

Based on current literature, automated platforms provide significant advantages in terms of reduced turnaround time, hands-on staff processing needs, and lower rates of aliquoting errors and sample carryover. However, impacts on test result variability appear dependent on analyte type and platform. Additional controlled studies are warranted to clarify effects on quality outcomes with different chemistry assays.

Overall, automated specimen preparation techniques appear beneficial for handling the heavy pre-analytical workload required to support fast-paced clinical chemistry testing in hospital laboratories. Thoughtful implementation offers the potential to enhance laboratory efficiency, reduce costs, and improve safety and clinicians' timely access to chemistry results that guide urgent patient care decisions. Further optimization of automated platforms could strengthen quality assurance across the full testing process.

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